DOCUMENT RESUME

ED 296 885 SE 049 411

AUTHOR Orlich, Donald C.
TITLE Physical Science Methods for Elementary Teachers. An Experimental Course. A Model to Improve Preservice Elementary Science Teacher Development. Volume V.
INSTITUTION Washington State Univ., Pullman.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE 15 Jun 88
GRANT TEI-8470609
NOTE 452p.; For other volumes in this series, see SE 049 407-412.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01/PC19 Plus Postage.
DESCRIPTORS *College Science; *Course Content; Course Descriptions; Curriculum Development; Elementary Education; Elementary School Science; Experiential Learning; Higher Education; *Preservice Teacher Education; Science Education; *Science Experiments; Science Teachers; Science Tests; *Teacher Education Curriculum; *Teaching Methods

ABSTRACT

A group of scientists and science educators at Washington State University has developed and pilot tested an integrated physical science program designed for preservice elementary school teachers. This document is a comprehensive guide to be provided to students in a physical science teaching methods course. Chapters include: (1) "Science as a Focus" (rationales, teacher as decision maker, trends and progress); (2) "Determining What Will Be Taught" (planning and objectives); (3) "Taxonomics and Teaching Science"; (4) "Questions and Teaching Science"; (5) "Using Science-Related Discussions"; (6) "Using the Real Stuff of Science: Inquiry"; (7) "Classroom Management"; (8) "Simulations and Games in Science Teaching"; (9) "Science Safety"; and (10) "Evaluating Students and Elementary Science Programs." Each chapter concludes with a list of references. An outline of the methods course content is appended. (CW)

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PHYSICAL SCIENCE METHODS FOR ELEMENTARY TEACHERS

A MODEL TO IMPROVE PRESERVICE ELEMENTARY SCIENCE TEACHER DEVELOPMENT

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FINAL REPORT

Submitted to the National Science Foundation

A MODEL TO IMPROVE PRESERVICE ELEMENTARY SCIENCE TEACHER DEVELOPMENT

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NSF Grant No. TEI-8470609
WSU 145 01 12V 2460 0102
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June 15, 1988

PHYSICAL SCIENCE METHODS FOR ELEMENTARY TEACHERS

An Experimental Course

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For
Elementary-Secondary Education 311
Physical Science for Elementary Teachers

1988

Volume V, Final Technical Report Submitted to the
National Science Foundation, WSU Project No. 0102
NSF Grant No. TEI-8470609

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CHAPTER 1

SCIENCE AS A FOCUS

During the 1960's and early 1970's our national concern for science reached, perhaps, an all-time peak. The advent of the "Space Age" made more people aware of the potential for scientific triumphs never dreamed of before. Science and scientists were accorded the highest esteem. Even at the time of this writing, our nation continues to place great faith both in our scientific and technological fields and in those persons involved in them. The mass media, especially television, have given the public a broad coverage of all fields of science and technology. As a result, these same media have contributed greatly to the stimulation of public interest in and understanding of science and engineering.

Yet, a comment frequently heard is that the schools of this nation have not focused adequate attention on science and scientific studies--this in spite of the fact that more and more scientific literature and supplementary learning materials have been made available to classroom teachers. The massive efforts of the National Science Foundation have stimulated elementary school science curriculum development to a state never before even contemplated.

In actuality, though, the "typical" elementary school teacher tends to be apprehensive about the teaching of science, despite the fact that science, technology, and scientific values permeate American culture. Perhaps that is the problem: Science is so much a part of our daily lives that we tend not to observe the evidence of its processes occurring within and around us, and, as a consequence, we think of science as a discipline exemplified by Albert Einstein's famous equations--understandable by just a handful of people in the world, and totally abstract to the rest of us. Elementary school teachers tend to ignore science because they have a high degree of anxiety about the topic, and, perhaps, fear that as teachers they do not know enough to teach it well.

But this need not be so. Science is similar to any of the other disciplines that are represented in the elementary school curriculum. Granted, the body of scientific knowledge is voluminous, and science has its own way of "knowing"--experimentation--along with a rather special vocabulary. But science is a means of generating new knowledge and, as one consequence, of making the world a better place in which to live.

The problems associated with teaching science at the elementary level have not resulted from indecision as to what to teach or even how to teach, but rather from what seems to be a fear of teaching science. We hope to dispel this fear. Our goal is to help you, as an elementary school teacher, to understand what science is and to become more confident in teaching it. We will provide a series of classroom-tested practices and techniques that will help each of you extend your knowledge of teaching per se to the teaching of one of the most fascinating fields known to humans--science.

Understanding Science Education

Why Teach Science in the Elementary Grades?

There are many lists of objectives and rationales for teaching science to elementary school students. High on the list is the fact that science is having an impact on the lives of all people in the world greater than that of any other cultural facet, perhaps even including religion. You will note that scientific and technological knowledge is the factor used to distinguish among developing nations, industrialized nations, and "post-industrial" nations such as the

United States. Thus, science affects people at their shops, homes, offices, transportation terminals, and even in their entertainment.

However, the materialistic well-being of a people is just one measure of the impact of science on the world's culture. Within our own nation we use science as one of the means by which to inculcate some of the following values.

1. Science is used to stimulate the critical and creative thinking skills of young people.

2. By knowing scientific facts, principles, and theories, our citizens better understand and appreciate the whole of the planet earth and the universe.

3. The study of science aids in decision-making by our government. Citizens with a better knowledge of the universe are better able to make more intelligent decisions--especially in the areas of the environment and those socially related considerations that are also a part of the world of science.

4. Scientific knowledge and its study lead to future careers in the field. These careers may not yet be invented. Recall that just a quarter of a century ago, there was virtually no computer industry, and jobs that required knowledge about electronic data

processing were few. With just one significant discovery--the transistor--the careers of millions of persons were created, and the economies of several nations expanded.

Among the other major goals of modern elementary science education, there is a general desire to stimulate the curiosity of all youngsters so that they can share in the excitement of scientific inquiry and investigations. Activity-oriented science programs allow students to conduct laboratory experiments that aid in the development of effective reasoning. These experiences also make young students familiar with the very methods and concepts used by real scientists in their daily work.

The Modern Rationales

The rationale of more contemporary science educators is that science is more than simple facts. Students must be given experiences that make them scientifically literate, i.e., make them aware of how a scientist works and of how the knowledge of science is generated.

A most important concern of the contemporary science movement is that students have direct experience with natural phenomena, that they be allowed to conduct scientifically related investigations. The use of activities means that the conceptual structure of elementary science is developed with appropriate teacher-provided guidance and experiences--points to which we will return many times.

Finally, students learn that science and all the findings of science are to be construed as being divergent and not absolute. All scientific findings are quite tentative, and all facts subject to re-interpretation. New experiments and new findings continually change the meanings of previously known facts or concepts. The latter may be the most difficult phenomenon for teachers and students at all levels to comprehend.

Scientific Processes

How does a student begin to comprehend the tentativeness of science? This comprehension comes from being immersed in activities that use processes associated with science. The Commission on Science Education of the American Association for the Advancement of Science identified at least 13 processes that are critical to the learning of scientific reasoning. These processes are predicated on the assumption that scientists use a distinct set of intellectual processes.

Scientific literacy is developed by devising experiences that reinforce these processes. Through funding by the National Science Foundation, these processes were, in fact, implemented in a curriculum entitled "Science--A Process Approach" (SAPA). The SAPA program is unique in many ways. It is the first total curriculum ever to be constructed by using the processes of the scientific community. The processes are the content to be learned, while the scientific concepts and educational experiences are simply the means by which the processes are applied. The writers and developers of SAPA identified generic scientific processes that are basic to all empirical endeavors. These processes are closely interrelated in the SAPA curriculum materials to show the relationships and the sequencing of the processes. Arranged somewhat in ascending order of complexity, the processes of SAPA follow.

1. Observing. Beginning with identifying objects and object properties, this sequence proceeds to the identifying of changes in various physical systems, the

making of controlled observations, and the ordering of a series of observations.

2. Classifying. Development begins with simple classifications of various physical and biological systems, and progresses through multi-stage classifications, including their coding and tabulating.

3. Inferring. Initially, the idea is developed that inferences differ from observations. As development proceeds, inferences are constructed for observations of physical and biological phenomena. Situations are constructed to test inferences drawn from hypotheses.

4. Using numbers. This process begins with identifying sets and their members, and progresses through ordering, counting, adding, multiplying, dividing, finding averages, using decimals, and working with powers of ten. Exercises in using numbers are introduced to support exercises in other processes.

5. Measuring. Beginning with the identifying and ordering of lengths, the development of this process proceeds with the demonstration of rules for measurement of length, area, volume, weight, temperature, force, speed, and a number of derived

measures applicable to specific physical and biological systems.

6. Using space-time relationships. This sequence begins with the identifying of shapes, movement, and direction. It continues with the learning of rules applicable to straight and curved paths, directions at an angle, changes in position, and determinations of linear and angular speeds.

7. Communicating. Development of this process begins with bar graph descriptions of simple phenomena and proceeds through descriptions of a variety of physical objects and systems, and changes in them, to construction of graphs and diagrams for results observed in experiments.

8. Predicting. To teach the process of prediction, the developmental sequence progresses from interpolation and extrapolation in graphically presented data to the formulation of methods for testing predictions. Predicting differs from guessing. When guessing, one uses "hunches" or "intuition". When predicting, one always uses data or previous knowledge about selected phenomena.

9. Defining operationally. Beginning with the distinction between definitions that are operational

and those that are not, this developmental sequence proceeds to the point where the students construct operational definitions to problems that are new to them.

10. Formulating hypotheses. At the start of this sequence, the student distinguishes hypotheses from inferences, observations, and predictions. Development is continued to the stage of constructing hypotheses and demonstrating tests of hypotheses.

11. Interpreting data. This process is introduced with descriptions of graphic data and inferences based upon them. The student then progresses sequentially through the following activities: constructing equations to represent data, relating data to statements by hypotheses, and making generalizations supported by experimental findings.

12. Controlling variables. The developmental sequence for this process begins with the identification of manipulated and responding variables (independent and dependent variables respectively) in a description or demonstration of an experiment. Development proceeds to the level at which the student, being given a problem, inference, or hypothesis, actually conducts an experiment, identifies the

variables, and describes how the variables are controlled.

13. Experimenting. This is the capstone of the integrated processes. It is developed through a continuation of the sequence of processes needed to control variables. This process includes interpreting accounts of scientific experiments, as well as stating problems, constructing hypotheses, and conducting experimental procedures.

It is assumed that there is progressive intellectual development within each process category. As this development proceeds, it becomes increasingly interrelated to the corresponding development of other processes. Inferring, for example, requires prior development of observing, classifying, and measuring skills. The interrelated nature of the development is explicitly recognized in the kinds of activities undertaken in grades 4 through 6, sometimes referred to as integrated processes; these include controlling variables, defining operationally, formulating hypotheses, interpreting data, and, as an ultimate form of such integration, experimenting. The integrated processes all require a combination of two or more specific processes.

These processes may form a collective set of teaching foci. By continually stressing these and building science content through them students and teachers alike begin to act like scientists.

We would also add one additional process--reading. Yes, reading is critical to all scientists. These people read about published studies in their journals. Scientists relate their own findings to that published by others in their field. So, reading is also a process of science--perhaps a subprocess of communicating.

How do teachers use these processes to teach science? Quite frankly, they make a decision to incorporate the processes into their instructional strategies. Let us examine the teacher's role as an effective instructional decision-maker.

The Teacher as Decision Maker

The art and science of effective teaching may be defined from many points of view. There are those who sincerely believe that "good teachers are born, not made."

If this were the case, good teachers could simply be identified without the expense of schooling. But as yet, no one has been able to identify those "natural" tendencies that produce good teachers. At the opposite pole, there are those who claim that teaching is nothing more than the simple application of the correct reinforces so that appropriate learner behaviors are elicited. The only problem with this position is that no one has discovered all of the positive reinforcers to be used each day with millions of children and hundreds of thousands of teachers.

These two positions can be viewed as two extremes of a broad continuum. Teaching as an "art" relies heavily on intuition as a basis for action, while teaching as a "science" depends primarily on a behaviorally oriented model. In the former approach, teaching is conducted by a more subjective, spontaneous method; in the latter, the process of education tends to be perceived as a very simple stimulus-response interaction--a reductionist position--with every skill subdivided into component tasks or procedures. It is very possible that there are natural traits in persons that predispose them to being better teachers; however, it is also essential that all teachers master a set of tested teaching skills to be successful. Thus, it is difficult to subscribe totally to either perspective, because both tend to be closed prescriptive systems. Yet, both approaches do influence what happens in the classroom.

Teaching as Interaction and Decision-Making

The act of teaching is always a dynamic interaction of individuals (teachers and teachers, teachers and learners, learners and learners--with materials, institutions, society), in which decisions constantly are being made by all concerned. We believe that science teaching must be deliberate and planned. As teachers plan for instructional interaction, they consistently and in most cases intuitively make critical choices.

For example, a teacher may decide to give one assignment to all students from a single science textbook series or to give multiple assignments from a variety of sources so that the students can select the ones of their choice. A decision may also be made to use multiple objectives, with accompanying learning materials that have been tailored to fit the instructional needs of various individuals or groups in the class. The teacher may then choose among a wide variety of options concerning how he or she will behave. Will there be a demonstration followed by a recitation period, a film, a filmstrip, or an audio tape?

A decision-model of teaching also implies that the teacher helps to create or alter the environment in which science learning takes place. Every teacher makes several hundreds of minor as well as major decisions each day. Not all of these decisions are made as a result of systematic and organized planning. Sometimes the choices are made intuitively. The use of intuition in teaching is quite prevalent. Many choices must be made intuitively, since the rapid pace of classroom learning demands instant decision-making. In these instances, teachers depend on experience and quick thinking to provide the most appropriate instructional technique. It may be suggested also that the intuition of experienced teachers is likely to be superior to that of the novice. Intuition is like an opinion in that its usefulness is dependent on the experiential background on which it is based.

Yet, in many cases, teachers depend on intuition to teach science when systematic and organized planning would be more appropriate. For example, a teacher may believe that a new science activity ought to be offered in the school setting, so a particular course of action is taken. Sometimes these "hunches" prove to be right and the results are beneficial to the students. But sometimes they are not effective or are inappropriate for the needs of the learners. At worst, they may cause the students to fail at the tasks and this causes them to dislike science.

Intuition as a sole guide to instructional planning represents a very limited view of the teaching process. Like the proposition that "good teachers are born, not made," the use of intuition alone restricts teachers from considering teaching as both science and art. It negates the development of a systematic planning pattern from which rational and consistent decisions can be made. It implies that intuition is the beginning and end of instructional effectiveness, rather than one aspect of the teaching process.

Too often the teacher who relies exclusively on intuition determines objectives and selects procedures that are more reflective of instructor needs than students needs. Thus, if a teacher feels like showing a film, then a film it is! Few of us would tolerate this mode of operation in arenas outside the realm of education.

Of course, we also propose that through meaningful science experiences, a teacher may know instinctively how to handle or react to a specific situation. For example, students are almost always "restive" prior to vacation periods. Thus the teacher need not try to introduce a new science concept on the Friday before a one-week vacation. A teacher can shift from an intuitive mode of operation to a more critical one simply by being aware that he or she is constantly making decisions that affect the intellectual, attitudinal, and psychomotor skills of learners.

Implicit within the concept of decision-making is the notion of responsibility. Teachers cannot "pass the buck." If a teacher makes decisions, he or she must be willing to take the responsibility for both their implementation and their possible consequences. For example, if teachers deliberately bias a discussion to fit their opinions, religious dogmas, or political tenets, then they are being agents of indoctrination. Some teachers whom we have known refuse to acknowledge that they are, in fact, being doctrinaire and claim that "this is good for the students." Of course, they would not consider it "good" if the students were to be swayed toward the opposite doctrines.

We illustrate this potential problem area because, in our opinion, many teachers do not recognize their responsibility for making decisions. There is often a tendency to blame the "administration" or the "school board." To be sure, there are administrative regulations and school-board policies that govern selected instructional procedures and even content. But most of the classroom instructional decisions are, in fact, made by the teacher. Our plea is that the teacher will take the responsibility for making those decisions, and that most of them will be made on a logical, systematic basis, and not on impulse.

One way to raise oneself to the level of cognitive consciousness (awareness) is to begin thinking with the "if-then" logic. If the teacher desires to encourage the students to learn through inquiry techniques, then he or she must provide the students with the initial learning skills with which to inquire and must supply the learning materials in a sequential, systematic fashion so that the students may apply the concepts being learned to real situations.

The "if-then" logical paradigm provides the teacher with a cognitive "map" similar to that used in generating rules and principles. The teacher starts thinking about causes and effects of actions and statements and about relationships between classroom activities and students. The teacher learns to obtain as much information as possible about both students and subject matter prior to the lesson and then develops a plan for success. This plan of instruction is based on the conclusions developed about the interaction between the science subject matter, the science processes, the student, and the teacher.

Teaching with Only One Style

If there is one truism in teaching, it is that there is no one way to teach science to anyone. With alarming frequency, educational "authorities" or "critics" announce that they have discovered the answer to teaching science. The literature is full of examples. Read about the advocates for behavioral objectives, team teaching, individually guided instruction, classroom learning centers, activity-oriented science, ITIP (Madeline Hunter's system), and field based study. Many of these approaches are based on sound analysis and investigation of the teaching-learning act. Typically, each approach is related to a specific kind of teaching activity, a specific philosophy of education, or a specific perspective of the structure of the basic discipline for which the program is developed.

Unfortunately, many advocates, in their eagerness to "spread the word" about particular approaches or methodologies, myopically attempt to convince other educators that *their* method is, at long last, the only right one. Such pronouncements, no matter how well intentioned, tend to be naive. The chances are likely that many teachers will not use *the* method; indeed, teachers who have never heard about *it* will find success simply by using more eclectic methods combined with wisdom, logic, and a sound knowledge of instructional techniques.

Our plea is for you to learn a wide variety of teaching strategies and apply them all--when appropriate--at just the right time!

Thus we caution you from the beginning; we will never say that we have *the* method for teaching science. We will present a series of options that are all usable and that will all yield humanely conceived educational results. In other words, we are following our own theory. If teaching science is a decision-making activity, then there ought to be divergent means by which to accomplish any instructional objective. That is what this report is about: knowing when to use a technique and what one can expect from using it. The context in which any method is used predicates its success; this is the notion of relevance. Those decisions that affect the kinds of learning that take place in classrooms will also be discussed.

Content and Process as Decisions

As you plan the teaching of science, it must be remembered that not only is the content of the lesson important, but of equal importance may be the processes that the students need to master the content. The Cunard Steamship Lines once advertised that getting there was half the fun! With teaching, the same metaphor as that expressed by Cunard is applicable. The students must know how to accomplish what you want. Let us examine a few situations.

If a teacher wants to teach about "levers" (the content) and the attendant applications of this concept, then the students must master various skills and processes. They must be able to understand the meaning of length, fulcrum, comprehend the concept of whole numbers, conceptualize the notion of proportions, and utilize a few other basic arithmetic operations. We propose that the processes associated with content are at times indistinguishable from the content; that is, both the thought processes and the resultant knowledge, skills, or information are the content. In this sense, there is "procedural content" and there is "cognitive content."

When prospective teachers are asked "As you anticipate teaching science, what concerns you most?" many, if not most, elementary education majors identify "knowledge of science" as their chief problem. It must be noted that while there is a tendency for prospective secondary school to be "subject-oriented," elementary school teachers tend to be "child-oriented." Their primary objective is to help the child grow and mature both mentally and physically--not just to teach science. The early school science experiences of children are oriented toward helping them to adjust from their home environment to the institutional dimensions of school. However, the elementary school teacher's approach, in which the child comes first and the science content second, does create some conflict within any school system.

In the junior high schools or middle schools, there is a transition period in which the emphasis shifts from a human-growth orientation to a subject orientation. But in nearly all high schools, teachers tend to be very academically inclined. The subject matter is first, last, and always the focus, although not to the exclusion of all personal considerations.

Who decided on these emphases? One could argue that "society" did. However, that argument is irresponsible. We argue that the teachers determined these priorities in response to the subtle pressures placed on them by institutions of higher education and perhaps even by society at large. It is commonly agreed that the schools of any society mirror that society. The wishes and beliefs of a society are subtly translated into the values, curricula, and instructions of the schools.

It is hard for all of us in science education to realize that processes must be taught with content, and it is even more difficult to understand the motives of any teacher who ways, "Well, if they didn't have the knowledge or techniques before they got into my class, that's too bad . . ." If students do not have the so-called prerequisite skills, then you as a teacher must provide them! If you do not, then your students will suffer failure. If you provide the basics, then your students will be successful in science; and they'll enjoy science. The decision is yours.

Goals and Schools

Believe it or not, people really argue and in some cases physically fight over the goals of the schools. In 1974, school patrons in Kanawha County, West Virginia, actually resorted to shooting at school buses and at each other because of a controversy about the goals of the schools, the English program, and the books being used to accomplish these goals. The opponents of the school claimed that inappropriate values and obscene teaching materials were being forced on their children and they were not going to allow it to continue (Young, 1974). Thus, while we assert that goals generally tend to be supported, it must be recognized that people also disagree with them. Let us address some societal considerations to illustrate the complexity that surrounds schooling and decision-making.

In elementary and secondary education, goals are continually stated, clarified, changes, and converted into school programs and ultimately into classes. But what are goals? Goals are broadly conceived statements that express, in general, what the schools should try to accomplish. However, goals, in our opinion, can be visualized as being rather static. The major goals of schools and education in the Western World have changed very, very little in the last 2,500 years. If you challenge this assertion, examine any set of goals for any period of time.

Obviously, state laws and local regulations all have an impact on the goals of schools. State legislatures, state boards of education, and local boards of education all have the legal right to require that the schools teach certain subjects, skills, or ideals. Arizona, for example, requires a course on the free enterprise system of economics. Virginia and several other states require a state history course for high school education. Nearly every state has a legislated physical education curriculum. As national goals become converted to laws and then to curricula--as reflected in books, tapes, films, teacher guides, and the like--there is also a tendency on the part of the state to establish the content and to imply the processes that will help to teach the content.

All this means--and we recognize that our treatment is very superficial--that teachers must ultimately make the decisions regarding how to teach and what to teach. Teachers begin to sift through the goals, establish priorities, and select those goals that they think are important. The most valuable goals will then take precedence in the classroom.

But remember: it is not the goal that is taught. The goal is simply the framework within which content, skills, processes, attitudes, and the like are taught.

Goals are not subdivided like apple pies. Goals are almost never attained. Rather, objectives are stated as action elements stemming from goals. Objectives then become the means by which we seek to achieve our goals, a topic that will be expanded later.

However, we must provide one caveat. The people of the United States have many nationalities, races, classes, occupations, philosophies, religions, attitudes, outlooks, and values. The diversity of our nation has led to a pluralistic society. Such pluralism also leads to a conflict of goals. Observe that in the typical school system there are social, moral, intellectual, political, and vocational goals. Some teachers tend to stress the goal regarding the improvement of our society. Others try to emphasize the goal to develop critical thinking. Still others attempt to develop individual students so that they may maximize their fullest potential. All of these accepted goals have led to eclecticism as a means of operating--i.e., we tend to mix parts of goals. One cannot teach critical thinking and at the same time stress that "teacher knows best." If a teacher is unknowingly eclectic, then that teacher is probably inconsistent in teaching practices. If you are cognitively aware of your eclecticism, you at least should attempt to avoid placing your own students in those situations that promote personal conflicts. In our society there probably always will be confusion and disagreement over some goals. As a teacher you may or may not be able to resolve either the confusion of the disagreement, which is all part of being pluralistic.

By now you probably feel that we have made our point: that the schools should encourage decision-making and that the decisions made should be ultimately consistent with the national goals. But as a teacher, what decisions do you make? Let us examine this question in detail.

Curriculum and Instructional Decision Areas

The key decisions that teachers make focus on science content and how it is taught. Most persons think of curriculum as "that which is taught in the schools." The difficulty in defining curriculum more precisely is that its meaning will be entirely dependent on one's philosophy, psychology, and teaching methods, because all of these factors determine the curriculum. There is no such thing as the science curriculum, since there is no universal agreement as to what is should include. In brief, the meaning of curriculum depends entirely on time, place, circumstance, and personal preference. On the other hand, instruction is how teachers interact with the curriculum and their students. While the latter is the focus, we must still present an overview of curriculum to establish a broader perspective of instructional methods.

Approaches to Curriculum Design

There are several approaches to curriculum design. We will briefly introduce five, which Elliot W. Eisner and Elizabeth Vallance (1974) have described as "conflicting" conceptions of curriculum. Then there will be an expanded treatment of the views of curriculum as (1) subject matter and (2) experiences.

Eisner and Vallance described five different orientations to curriculum: (1) development of cognitive processes; (2) technology; (3) social reconstructionism; (4) self-actualization; and (5) academic rationalism.

The first orients schooling toward cognitive skills development and training. The second centers the curriculum around the processes of efficiency and emphasizes those traits associated with productivity. The third views education as having a basic societal component and thus stresses social goals over individual ones. The fourth, self-actualization, is the opposite of social reconstructionism and stresses that the individual's role is paramount in the educative processes. The fifth stresses the importance of transmitting our primarily Western cultural heritage to our youth.

There are many theories on curriculum that approach the topic from social, psychological, philosophical,and individual perspectives. We would like to explore two approaches that are subsumed under Eisner's and Vallance's five orientations, but yet are autonomous entities. The first approach views the curriculum as subject matter; the second, as a set of experiences. There are many curriculum theories, but most approaches can be categorized under either *subject* matter or experiences. (This is an oversimplification, but it may help at this point.)

Curriculum as Subject Matter

Those who view curriculum as subject matter usually assume that the primary goal of education is to transmit our cultural heritage to our students. This position presupposes that the school's major function is to transmit information to children that is considered desirable for them to know. Past events are usually accepted as having inherent value; the science, literature, language, beliefs, values, art, music, and methods of computation that have existed in the past are thought to be sufficiently important to warrant being passed on to all students. John Dewey (1916) noted that no culture can survive unless selected aspects of the culture are directly, consciously, carefully, and thoroughly transmitted to the children who are to inherit the culture.

The goal of the subject-centered approach is to stress knowledge of science subject matter for its own sake--that is, it is simply good for children to learn science. The subject possesses value per se. It may or may not be a means to something else; if it is, it is incidental. However, science content alone may or may not induce a child to appreciate or understand the cultural heritage from which the science content emerged.

For any culture to survive or to renew itself, it is an anthropological fact that there must be a conscious attempt to transmit the cultural heritage to the new generation. Therefore, those who believe in a subject-centered approach to curriculum are, in part at least, quite correct in the stress they place on subject matter.

Curriculum as Experience

The subject-oriented approach is countered by the position that describes curriculum as a set of "desirable experiences." The emphasis is not on knowledge of any particular piece of information but on a process or skill to be mastered. Subject matter is to be used to develop facility in this process or set of processes. For example, students must acquire the ability to apply scientific concepts. To promote this ability, biology, chemistry, physics, earth sciences and other science courses are taught. The subject matter is a tool or a means; it is not an end in itself. For example, to be able to make political decisions, students study social problems, geography and the impact of science on a group of people. By studying these subjects and by having a set of experiences, the individual is presumed to become a more "effective" citizen. These experiences include not only studying books but also such activities as conducting and observing real experiments or working with scientists and technicians.

Analysis of the Two Basic Approaches to Curriculum

Both curriculum theories can be criticized. The subject-matter curriculum may produce a "well-trained" individual, one who knows "science." However, the subject-centered curriculum does not necessarily produce a person who is critically aware of how one knows, does, and thinks. Such a subject-oriented student may not even be aware of operating under an authoritarian approach.

Those who deny the intrinsic importance of subject matter are also open to criticism. What they have done, in effect, is to separate the content of knowing from the process of knowing. They have somehow assumed that while knowing is important, what is known is not.

The weakness of the experience approach may be seen in some of the recent curricular modifications brought about by the experience-centered advocates. If one teaches science only with concrete experiences, then the child does not appreciate reading science. A balance is needed: Experience and Content and Reading.

One curricular ideal that could have had a great impact on our schools was that proposed by John Dewey. Dewey advocated a curriculum based on problems. He defined a problem as anything that gives rise to doubt and uncertainty. Dewey did have a definite idea of the type of problem that was suitable for inclusion in the curriculum. He thought that the problems to be studied should meet two criteria: (1) they should be significant and important of the culture; and (2) they should be important and relevant to the student. Genuine comprehension and successful application of Dewey's problem-solving theory also hinge on extensive knowledge of process--how to define and solve problems. Although cursorily treated here, the topic of inquiry and problem-solving will be discussed in great depth.

It is apparent that recent reforms in the science and mathematics curricula are based on the problem-solving approach; especially the Science-Technology Society programs now being espoused. These curricula involve problems that must be solved by students, utilizing the scientific method. These curricula stress "discovery" of relationships and "inquiry" into the "structure" of the world of things and ideas. These same terms were used by Dewey in the early 1900s.

Curriculum and Individual Differences

Although educators have known for some time that there are differences among human beings, this knowledge has been applied only recently in the schools. For many years all students, studies approximately the same subjects. American curriculum-makers have attempted recently to devise curricula to match different levels of ability. In particular, through federally sponsored projects, there are curricula for the average, for the bright and gifted, and for children who are wither slow learners or retarded. These curricula all require varying instructional methods and additional teacher preparation.

Another factor that affects the curriculum is an awareness of the students' home environments. It has been realized that urban children have a markedly different outlook, set of experiences, and interests than suburban or rural youth. Investigations and projects have been carried out to devise different teaching methods and more appropriate curricula for urban children. This curricular practice is of very recent origin and is found usually in larger metropolitan areas.

In addition to adapting education to the needs of urban children, schools, in the last several years, have been challenged to produce a curriculum that is truly representative of their multicultural student populations. Compounding this task is the reality that most curricula have been designed by the middle class for the middle class. The texts, their illustrations, the contents, the teaching methods, and the grading practices are designed to further middle-class values and beliefs. And yet, educators tend to forget that science is one of the major disciplines that bridges the cultural gap. Teaching science to all children regardless of race, color or creed provides them with a truly universal "tool."

Analysis and Implications

Why is the American curriculum this way? The answer is complex. Because of our pluralism it is unlikely that one viewpoint, one curricular emphasis, one instructional method, or one set of values will long predominate. The results of different groups concurrently working toward different goals are seen in

American schools. Thus the current accountability emphasis in schools is in response both to the higher cost of education and to declining standardized scores. The past emphasis on math and science is essentially a product of the Cold War and more recently a product of our "Trade Deficits."

The science curriculum will be modified--almost without limit--to accommodate the times, the location, the tensions, the economic events, and the wishes of any particular population. Americans have believed for a long time that the curriculum should be responsive to the wished of the American people. But how does a school determine that ought to be taught? If it is true that the squeakiest wheel gets the grease, and if dozens of wheels are squeaking, groaning, and shrieking, how are schools personnel to decide which wheels most deserve attention?

Today's curricula are the result of philosophical conflicts, not only among professional curriculum-makers and laypersons but also within a single person's views. As a people, America has not yet determined what should be science education for all and what should be science education for those who are able, talented, and intelligent--or for those who are not.

We tend to be ambivalent in our stressing of academic excellence for the bright and in our emphasizing of formal education for all young people, regardless of their intellectual capacities.

A pluralistic society predictably yields the kind of curriculum that has been described--a patchwork. Such a curriculum will produce conflicts and confusion in educational psychology, methods, philosophy, administration, and finance. Simple solutions and absolutistic thinking will not work. What is required first of all is an understanding of the nature of our society and the manner in which curriculum is created. Once teachers have this understanding, they will be in a position to modify and improve the science curriculum.

What can be done about the problem? Teachers, if they are to attain greater professional stature--that is, to become more independent and autonomous--must seek a more decisive and vigorous role in influencing science curricular decisions. It is largely a social-professional conflict that causes teachers to succumb to a vast and powerful array of pressures that distort and weaken the many different science curricula. Yet better-educated teachers who understood the basic techniques of science instruction would not need a detailed guide to tell them how to teach science. Science teachers would not have to yield to the pressures of ultra-right-wing groups if they were sure of what constitutes science. Biology teachers with a greater knowledge of the biological sciences would not be forced to yield either to nineteenth-century thought or to legislators whose knowledge of experimental science is negligible. In addition to being aware of the nature of our culture, teachers need to know more about the science that they are teaching, and they need to organize themselves into the kind of associations that can resist biased or reactionary community pressures.

We have not resolved the problem but have illustrated how professional concerns may become subordinate to social concerns in a typical American school. Bear in mind that, in the United States, plenary control of the public schools is vested in the fifty state legislatures. If education appears to be more of a political process than an educational one, that may be the case.

The argument between advocates of method and supporters of science subject matter is, of course, outdated and absurd, but yet it continues to rage. To teach science, one must teach concepts. That is, one cannot separate legitimately the content of knowledge from the process of knowing. All teachers need to be reasonably sophisticated and informed about science subject matter that is appropriate to the age, interest, and intelligence of the students they teach. In addition, they need to be aware of the appropriate methods, techniques, philosophies, psychologies, and learning theories of education by which to teach science content and apply scientific processes most efficaciously. This discussion may appear somewhat complex; as a matter of fact, we have merely scratched the surface of curriculum problems. Our intent here is that of "awareness setting." Other courses will expand these ideas, but we will illustrate how the teachers selects the most appropriate science methods or technique.

Trends and Progress in Elementary Science Education

The reform movement which brought out the current program and teaching practices in science education began during World War II. During that time it was recognized that there was a need for changing some of the teaching practices in science, particularly with the increase demand for persons with scientific backgrounds and technological skills. In 1957, Sputnik, more than any other single event, provided the opportunity for educators to update and assess instructional programs.

Prior to Sputnik, practices in science teaching emphasized science as a deductive process where pupils were given scientific facts, generalizations and asked to verify them. This often was simply a matter of retrieving information from a textbook, lecture, class discussion, or personal experience and submitting this as evidence. The omnipotence of the teacher who had at his or her disposal irrefutable facts was taken in highest regard.

After Sputnik, leading scientists, psychologists, mathematicians, and other scholars joined with educators to stress instructional and curricular reforms. The post-Sputnik reform was unique in at least three ways. First, it marked the initiation of large numbers of scientists, educators, and learning psychologists working jointly in the development of science and mathematics curriculum materials for school age students. Second, the curricular programs that were developed were unique and different in that they began to emphasize the processes and big ideas in science. Third, the primary level of support came from federal grants and foundations rather than through state or local monies. Donald C. Orlich (1980) expressed developments of the previous 20 years as "stimulating elementary science curriculum development to a stage that may not be achieved again."

Two major tasks which the developers of the new elementary curricula emphasized were: (1) building new science programs that were consistent with the abilities and needs of children, and (2) training teachers to implement these programs.

Although there is no general consensus regarding the goals and objectives of elementary science, there seems to be general agreement regarding a few areas. Paul Blackwood's survey (1965) of practices in elementary science programs reveals that most science programs embrace seven broad goals. These are to:

1. Help children develop their curiosity and ask what, how, and why questions.

2. Help children to learn to think critically.

3. Teach knowledge about typical areas of science study such as weather, electricity, plants, animal life.

4. Help children learn concepts and ideas for interpreting their environment.

5. Develop appreciation for and attitudes about the environment.

6. Help children develop problem-solving skills.

7. Develop responsibility for the proper use of science knowledge for the betterment of man (p. 180).

Since 1957, (the year of Sputnik), 53 major science or mathematics curriculum projects have been funded by the National Science Foundation on Science and Technology, 1976). The three most widely recognized elementary school programs are listed below:

1. Elementary Science Study (ESS)
2. Science--A Process Approach (SAPA)
3. Science Curriculum Improvement Study (SCIS)

An in-depth investigation would reveal that these programs possess several common elements. First, they deal with a broad spectrum of content, ranging from sophisticated principles in physics to growing seeds. Second, there is a minimal amount of planned reading. Third, most programs use manipulative multi-media materials that in effect replace the conventional textbook. Fourth, these programs devote primary attention to student involvement and secondary attention to memorizing cognitive information. Finally, in-service training of teachers is considered of paramount importance by the developers.

There is not widespread agreement among science educators regarding the purposes, instructional strategies, or content emphases of elementary science curricula. In fact, the professional literature reveals the emergence of at least three differing philosophical positions which we state as questions.

1. What content should be included?
2. How much and what kind of teacher preparation is necessary?
3. How should the material be presented?

General Findings

Studies conducted during the past decade appear to indicate a high level of success of these newly developed materials. The effectiveness of SCIS, SAPA. and ESS programs on children, Ted Bredderman (1982) indicated that children involved in these programs show higher level thinking skills and better problem-solving skills. In addition, some studies showed performance in math and reading as well. The positive effects of activity-centered science in improving reading skills were also reported by Ashly Morgan, Stanley Rachelson, and Baird Lloyd (1977).

James A. Shymansky, et al. (1974) and Jane Boyer and Marcia Linn (1978) state that students who have experienced activity-centered science programs are better independent problem-solvers and are more self-assured. The value of SCIS in improving logical thinking was also reported by Marcia Linn and Herbert Thier (1975). Gerald Krockover and Marshall Malcolm (1977) found that the SCIS program was effective in improving self-concept. The carryover of these improved attitudes into other subject areas is implied by the work of M.D. Caplin (1969), who reports a positive relationship between self-concept and achievement.

John Penick (1976) and Terry Davis et al. (1977) reported that students experiencing SAPA scored higher than textbook-taught students on creativitiy tests, while performing at least as well on standard achievement measures.

Harold Jaus (1977) conducted studies which indicate that activity-based science improves children's attitudes towards school as well as toward science.

Unfortunately, even though the research appears to be both substantial and conclusive, current trends appear to indicate that our educational systems are reducing the amount of time spent teaching science that the type of science taught is becoming more traditional and textbook-based. William Maben (1980) states that 50 percent of elementary teachers that he surveyed felt there was not enough time in the school day to teach science.

Michael Andrew (1980) conducted two surveys in New Hampshire, one in 1970 and a follow-up in 1977-78. Both surveys reflected that "science is not being taught as a major part of the curriculum in many elementary schools in New Hampshire." Andrew concluded that his surveys revealed "alarming trends" in respect to the science being taught in the elementary schools. He implies that these trends may be nationwide and should be a cause for concern. Both studies indicated that lack of time was primary reason for not teaching science. The 1978 study also indicated a primary reason was inadequately prepared teachers.

In comparing Andrew's studies, there was a significant decrease in time allotment given to science between 1970and 1977-78. It appears that elementary school science is drifting toward one day per week instruction. Whatever the reasons, it seems that science is not treated as basic subject in the elementary school curriculum and is presently losing rather than gaining status.

Andrew reports further that science was given a low priority rating by 13 percent of the elementary teachers in 1977-78, up rom 5 percent in 1970. The percentage of teachers who gave science a high priority rating also was down, from 9 percent in 1970 to 5 percent in 1977-78. These trends are alarming in light of the research evidence as it relates to hands-on science and its impact on the elementary school child. It appears that science at the elementary level is becoming an occasional or supplemental part of the educational program.

A list of findings of elementary science usage during the past decade are indicated in the Table 1-1.

Table 1-1

Use of Selected Progress Programs in K-6 Science

	Program Type		
Research Source	ESS	SAPA	SCIS
Gullickson (1971) (midwest)	11%	15%	8%
Gullickson (1974) (midwest)	14.6%	8%	5.4%
Weiss (1977) (national)	15%	9%	9%
Peter Gega (1980) (national)	not	3%	Life 3%
Heiligenthal (1980) (Iowa)	K-3 11.8% 4-6 20%	K-3 16.5% 4-6 10.6%	K-3 14.2% 4-6 10.6%
Anderson (1980)	13.2%	10.6%	8.6%

Although Peter Gega (1980) in a national survey reports that only a small percentage of schools are using the NSF activity-based programs, two 1980 studies conducted in Iowa (Heiligenthal, 1980; and Anderson, 1980), indicate that the usage of NSF curricula in Iowa elementary schools is between 30 and 40 percent. They also report that these materials have a higher percentage of use in larger districts.

In a study conducted in 1980, Jan Anderson, University of Northern Iowa, reported the average time spent teaching science in Iowa elementary classrooms:

1st grade	44 minutes/week
2nd grade	51
3rd grade	66
4th grade	101
5th grade	106
6th grade	115

These are less than those reported by Iris Weiss in a 1977 survey; however, these times appear to be quite comparable with those reported by Paul Blackwood in a survey conducted in 1962.

Blackwood (1965) listed barriers to effective science teaching, including lack of consultant services, lack of supplies, lack of room facilities, insufficient funds, insufficient knowledge, lack of in-service opportunities, inability to improvise, unfamiliarity with methods, not enough time, lack of community support, lack of teacher interest, what to teach is not determined, and other areas are deemed more important.

Stanley Helgeson, et al. (1977) concluded that the "back to the basics" movement and the financial situation of the last few years have had a large impact on and are reflected in science education trends. (The preceding section was modified and adapted, with permission, from a professional paper submitted by Jan Anderson, 1980.)

Some Washington State Data

In 1984, John P. Smith, Donald C. Orlich and Donald G. Dietrich reported on the status of K-12 science teaching in Washington state. They found that elementary teachers enjoyed teaching sciences by "doing" it, i.e., the hands-on approach. But, the teachers reported that "getting ready and the time involved" were the least enjoyable part. It is obvious that it is not enjoyable as the authors found that science was only taught about 40 minutes per week in grades 1-3, and about 60 minutes per week in grades 4-6. These times appear to be even less than those reported by Anderson.

Teachers reported not teaching science because they lacked (1) science knowledge and college science preparation, and (2) interest. Teachers ranked science in fifth place in the school's program behind reading, mathematics, language arts and social studies. However, teachers did respond that it was important to stress both science concepts and science processes when science was being taught.

Thus, it might be conservatively concluded that science teaching in America's elementary schools is a chance event, being contingent on a teachers's personal preference to instruct the subject in actual practice. To be sure, there are school districts with well taught elementary science. But, they are the exception, not the rule.

Probable Directions

Some current directions in elementary science which appear to earmark trends for the early 80's in elementary science as follows.

1. Increased textbook usage in schools. There has been a growing concern on the part of some educators and citizens that knowledge objectives have been de-emphasized too much. The trend is toward more content through the utilization of textbook-based materials.

2. Changing from a low degree to a high degree of teacher adaptation. There appears to be more responsibility being placed upon the teacher to select from the wide assortment of hands-on materials available in constructing a science program that best

fits local needs. In many cases this involves cross-correlation of NSF developed materials with new textbook programs. Teachers are also expected to adapt materials for students of differing abilities and for those with physical or emotional handicaps. Elementary school teachers simply do not have the time to do the above!

3. Development of programs oriented toward the general student. There appears to be a general concern for reducing vocabulary development in elementary science. Textbooks devote considerable concern to readability and reinforcement of very basic skills. Publishers tend to provide a very limited array of styles, but a great variety of concepts and content.

4. Greater emphasis on deskwork and teacher demonstrations. The effect of inflation has also impacted elementary science. Deskwork and demonstrations can lower program costs. It is becoming more commonplace, even in the NSF developed materials, to suggest larger work groups or to convert a hands-on activity into a worksheet or picture-reading activity.

5. An emphasis on revising previously developed materials rather than developing new programs. The practice of bringing together scientists, educators,

and learning psychologists for the development of new and innovative programs appears to be out of favor at the present time. New directions seem to emphasize the revision of the programs of the 60's, with integration and adaptation of the activities formerly present in these curricula, into new textbook series.

6. Greater emphasis on quantitative measurement and use of metrics. The science programs have responded to the need for precise expression and measurement since the advent of process science in the sixties. However, current trends reflect the utilization of SI metric and a renewed effort to reinforce basic skills through content areas such as science.

7. Development of a consciousness for the social ends of education. The 60's appeared to reflect a science which was theoretical and did not apply to contemporary society. New programs tend to develop a more humanistic orientation with considerable emphasis on the people of science and contemporary societal and environmental issues. But, these programs require more time to teach and thus are not adopted widespread.

8. Concern for the individual. Elementary science programs are being modified from being almost

totally cognitive to placing considerable emphasis on the affective domain. Some attention is being given to how a child feels about learning. Educators are renewing conceptual schemes and searching for the most comfortable setting for children to develop basic cognitive competencies. Greater concern is being directed toward the level of reasoning of the individual student. Further, science programs and materials are being developed for handicapped and mainstream children.

Conclusion

It appears that elementary science is on the verge of becoming an occasional or supplemental part of the curriculum, particularly in the first three grades. Research studies indicate that programs such as ESS, SAPA, and SCIS have been effective in (1) developing higher level thinking skills, (2) improving attitudes toward science and school, (3) contributing to the development f reading, and (4) improving problem-solving skills. It is ironic that the reduced emphasis in science appears to generate current teaching priorities which are in direct opposition to the primary goals of American education. There is now, possibly more than ever before, a real need for quality science instruction in the elementary grades. The leadership to stress science in the schools now falls on those who are newest to the system!

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CHAPTER 2

DETERMINING WHAT WILL BE TAUGHT

Planning for Successful Instruction

One hallmark of schooling as an organized activity is the process called planning. We encourage you to instruct science in a systematic manner. Thus, a substantial proportion of your time and activity will be concentrated on planning--deciding what and how you want your students to learn. It appears that teachers who work in effective schools exhibit four common traits: (1) they are well organized in their planning; (2) they communicate effectively with their students; (3) they have high expectations of their students; and (4) they continually monitor their students' work and progress.

We may generalize that, although science learning can take place anywhere and spontaneously, the more systematic the teacher, the greater the probability for science success. Instructional planning or lesson planning implies the establishment of priorities. The setting of priorities mandates a continuous set of teacher decisions. The objectives that you specify establish science learning priorities for the students.

We do not wish to imply that the learners may not specify their science objectives. But, to be realistic, the teacher, is responsible for establishing the priorities through explanations, learning centers, discussions, learning modules, assignments, use of textbooks, and "hands-on" science experiences.

It must also be thoroughly understood that all plans and priorities are tentative and probabilistic. Plans are estimates of what ought to take place. What actually transpires may be different from the original intent--even with the attainment of very specifically stated and written objectives. Teaching and learning are interactive endeavors and you can't control the learners.

By preparing written lesson plans, the priorities about time, learning materials, objectives, and type of instruction are all made known in advance so that success may be maximized for two important groups--the teachers and the students.

Performance Objectives

There is one segment of educators that stresses that objectives ought not emphasize what the teacher will be doing, for example, teach about photosynthesis but rather, should identify the performance or behavior that is to be expected of the students as a result of instructional experiences. For example, if the instructional topic happens to be the introduction to photosynthesis, then one performance objective may be for the student to "illustrate the general reaction of the photosynthetic process, using the components of O_2, H_2O, CO_2, glucose, sunlight, and chlorophyll in the correct sequence of events"; or "illustrate the major steps of the Water Cycle, using the textbook as a source."

Since the emphasis is on "observable" student outcomes, these objectives are called performance or behavioral objectives. Instructional, learner, and specific objectives are also used as synonyms, but these terms should not confuse you. The main point is that you should demonstrate the ability to distinguish between objectives that emphasize student behavior and those that state what the teacher is supposed to do.

One important use of behavioral objectives is that they give the teacher clearer and more precise guidelines to achieving specific student outcomes; for example, the expected student performances or behaviors for which the teacher is responsible in class. That is, the objectives prescribe exactly which behaviors the students must manifest as a result of the instruction. Likewise, performance objectives are given to students prior to instruction to inform them specifically of what they will learn to do. This eliminates much of the guesswork related to teaching ("What should I teach today?") or to the student's dilemna ("What should I study for the test?").

Note that there is an implicit assumption that, because the student is told in advance what is expected, the student will be self-motivated to do the tasks. This is not the case, just as it is not always the case if general statements are made to students about what is expected of them. A more detailed critique of the uses and abuses of performance objectives will be presented at the end of this chapter.

Performance objectives are widely used in a variety of instructional systems and, as a prospective teacher, you need to understand and develop the technical skills that are necessary to prescribe and state these types of objectives. If you ever become involved in any "individualized" program, it is mandatory that you skillfully write and analyze performance objectives, since nearly all individualized programs using "mastery" learning techniques referenced to performance objectives. Furthermore, some states, by law, as does the state of Washington, require that they be specific as do some school districts, by policy. Finally, computer assisted science instruction is keyed directly to learning objectives that are carefully prescribed.

A particular demand on teachers to make use of performance objectives has come from the Education for All Handicapped Children Act of 1975 (Public Law 94-142), which requires that all handicapped children be taught in the regular classroom to the greatest possible extent. As part of "mainstreaming" handicapped children into the classroom, an Individualized Educational Plan (IEP) must be prepared for each special student. Each IEP must be written in terms that identify the specific learning outcomes expected of the student. This means that each plan must contain performance objectives for each student, which allow for precise measurement of the degree to which the special student has mastered the prescribed task. Certainly, the IEPs required by PL 94-142 will cause many teachers to become highly skilled in the writing of performance objectives.

Beginning the Process

The identifying and writing of performance objectives take detailed planning. Often one begins by identifying objectives at a very broad level, then working toward specifics. Developing performance objectives is, therefore, a deductive process. The direction of movement is from a general frame of reference to more specific ones. Most simply, there are three levels of specificity. These levels may be classified as: (1) general (often synonymous with goals); (2) intermediate; and (3) behavioral or performance. This chapter deals only with the latter that is, behavioral, performance, learner, specific, or instructional objectives.

Before closure is made here, it must be understood immediately that performance objectives are not usually the scientific process objectives about which we discussed earlier. The process objectives, to be sure, require student performances. But, the processes are a means by which a teacher conducts the science lesson. They are not specific behaviors. This may sound confusing, but we will amplify the distinction.

Deciding which objectives are valid and relevant in any course or program is a very important and adifficult part of curriculum planning. To help in this important decision, educators have been urged to examine three principal sources of objectives by Ralph W. Tyler, a pioneer in the field of behavioral objectives. Tyler (1949) stated that the sources for objectives ought to be: (1) the learner; (2) studies of contemporary life outside the school; and (3) the subject matter itself, the respective disciplines.

If you were to follow the rationale of some proponents of performance objectives to its ultimate conclusion, you would find yourself creating an individual set of objectives for every student. While this may be an interesting "goal," we view it as being fiscally and procedurally not feasible. It is doubtful that any society with limited resources would decide to pay for total individualization of instruction. Fortunately, such individualized instruction is not required to provide effective, appropriate, and meaningful learning opportunities for all students.

Intermediate-range objectives, (those 13 processes) while useful as guidelines, are still too general for direct implementation in instruction; thus the classroom teacher states even more specific objectives so that explicit direction is given to learning. These specific objectives usually are called behavioral objectives, because learning is defined as an observable change in the behavior of students. That is, learning is assumed to have occurred when the student demonstrates some behavior that could not be shown prior to the learning experience. Therefore, at the instructional level, objectives are statements about the behavior of the student. Rather than identifying what the teacher will do, specific performance objectives describe what the learner will do.

Rationale for Performance Objectives

While many teachers are able to recognize educational goals and to translate them into effective conditions for learning, others have not carried their thinking beyond the stage of selecting the content to be presented. The danger is that the teacher will not recognize effective ways of reaching the necessary objectives if, in fact, the objectives are not individually formulated. Also, unless students know what the objectives are, they are likely to resort to memorization and mechanical completion of exercises rather than carrying out relevant learning activities. When the teacher tells the student what is expected, a model is provided around which learning activities can be individually organized. When this is done, the teacher and student have established a "perceived purpose" for all that is to follow. Unless objectives are specifically stated, it is impossible to determine the student's achievements at any given moment. Therefore, statements that define what is expected of the learner must be available. These are the basic assumptions associated with the performance objective movement.

Currently, over 80% of the state legislatures or state education agencies are considering or have already mandated plans that "make the schools accountable." In general, making schools accountable means that teachers will be evaluated in terms of how their students perform. The only way that teachers can "prove" that their students have learned is by providing measurable evidence that their students are different at the completion of a sequence of instruction than they were before instruction. One way a teacher can provide measurable evidence is by stating in advance of instruction the performance they expect of their students performance objectives. (Obviously, there are other ways.) Therefore, in the many states where accountability programs are a part of the teacher's daily life, performance objectives have become a primary part of their planning and implementing of instruction.

It is assumed that teachers involved in preparing and using behavioral objectives have a mastery of the academic discipline, science. This assumption is not valid for the majority of elementary school teachers. Therefore, because the preparation of behavioral objectives demands a critical analysis of the subject matter to be learned, a variety of aids such as textbooks, curriculum guides, and print and nonprint materials may be useful to elementary teachers. But, the teacher ultimately makes the decision.

Taxonomies of Behaviors

In 1948, after an informal meeting of evaluation specialists, a decision was made to formulate a theoretical framework to facilitate more precise communication about the learning process. It was agreed that such a framework would best be devised through a system of classification of the goals of the educational processes. It was the assumption of the group that educational objectives, stated in behavioral form, are reflected in the behavior of individuals.

That is, behavior can be observed and described, and these descriptive statements can be classified.

The plan for classification involved a complete taxonomy in three major parts--the cognitive, the affective, and the psychomotor domains.

The Cognitive Domain includes those objectives that deal with the recall or recognition of knowledge and the development of intellectual abilities and skills. This is the domain in which most of the work in curriculum development has taken place and in which the clearest definitions of objectives phrased as descriptions of student behavior occur.

The Affective Domain concerns attitudes, beliefs, and the entire spectrum of values and value systems. This is an exciting area which curriculum-makers are beginning to explore.

The Psychomotor Domain attempts to classify the coordination aspects that are associated with movement and to integrate the cognitive and affective consequences with bodily performances.

These taxonomies were designed to act as a classification system for student behaviors that represent the intended outcomes of the education process. By combining the principles of the taxonomy with the careful preparation of performance objectives, the teacher can focus instruction on outcomes that vary from the simple to the complex. Using the taxonomy, the teacher can prescribe objectives to build simple, entry-level skills for students or to develop complex, high-level skills that meet the student's individual needs. A taxonomy as an analytic "tool" is most useful when the teacher is attempting to develop a specific IEP or when he or she is building entry-level skills for educationally disadvantaged children. Thus by understanding the taxonomy, the same classes of behavior may be observed in the usual range of subject-matter content, at different levels of education, and even in different schools. Chapter 3 is devoted entirely to the cognitive taxonomy where further clarification and amplification is made.

Elements of Performance Objectives

Although performance objectives are written in a wide variety of styles, there are generally three elements (Mager, 1962) that can be included in the specification of a performance objective:

1. The statement of an observable behavior or performance on the part of the learner.

2. An elaboration of the conditions under which learner behavior or performance is to occur.

3. The prescribing of a minimally acceptable performance on the part of the learner.

You will often observe the first element in most performance objectives meeting the specification of the *intended* behavior or performance. According to purists of the skill, *only* when all three elements are stated is an objective written appropriately. As learners of the skill, you should always state the three elements for practice. This repetition will then give you insights (nonbehavioral term) into how you will feel (affective term) about their use in your teaching or how to evaluate (cognitive term) curricula that use such objectives. Again, it will be your decision (affective behavior) as to what style *you* choose. It was *our* decision (arbitrary and cognitive behavior) to illustrate a three-element type.

Element One: The Performance Term

The first element of a behavioral objective is the specification of a word, generally a verb, that indicates how the learner is performing, what the learner is doing, or what the learner is producing. Words such as *match*, *name*, *compute*, *list*, *assemble*, write, circle, and classify result in observable learner behaviors that will help you to evaluate the achievement of behavioral objectives.

For example, if you state that the student must name the symbols of ten listed chemicals, the student's behavior is manifested when this performance takes place; and everyone will know that the student has attained the stated objective. In one sense, the quality of the performance acts as an evaluative measure. We will expand this point under criterion reference, which follows later.

The specifications of the performance, of course, are derived from the goals and intermediate objectives. As you teach science, one goal always will be to provide instruction about the way scientific content is discovered. An intermediate objective surely will be to study how to distinguish between observations and inferences, i.e., two processes or intermediate objectives. Specific performance objectives may be as follows. The learner will:

1. Identify objects that are solid and those that are liquid.
2. Read a temperature in degrees celsius.
3. Identify three objects by their odors.

4. Identify two statements that are inferences.
5. List three observations that support a stated inference.
6. Classify 10 items by the characteristics of being "magnetic" or "non-magnetic."
7. List observations which can test a stated inference.

All of these objectives are written with a prescribed student performance in mind. Table 2-1 contains a handy list of action verbs that will help you in constructing the first element of performance objectives.

Careful examination of the table will show you that it contains mainly *transitive verbs*, the "action verbs." They suggest that the actions are done to objects which must also be specified. The objective thus tells what will be done. This is critical, since the intended action is meaningless unless the objective is clearly specified.

Words such as *know*, *understand*, *analyze*, *evaluate*, *appreciate*, *comprehend*, and *realize* are not action verbs. While such terms are important in the process of learning science, they are not observable actions

TABLE 2-1

Some Action Verbs that Describe Observable Cognitive Behavior

---

A

alphabetize
apply a rule
arrange
assign values

B

bisect

C

calculate
chart
circle
classify
combine
complete
compute
construct

D

define
describe
diagram
disect
discriminate among
distinguish between
divide
draw
duplicate

E

enumerate
extrapolate

F

factor
figure
fill in
find
formulate

G

graph

I

identify
inscribe
insert
interpolate
itemize

J

join

K

keep

L

label
list
locate

M

manipulate
mark off
match
measure
memorize
mix

N

name

O

order
order alphabetically
order serially

P

point out
predict
put in order

Q

qualify
quote

R

rank
rate
reproduce

S

select
specify
state a rule
substitute
subtract

T

tabulate
transcribe
translate

U

underline
undertake

V

verbalize

W

write

X

x-ray

Y

yell

---

and thus cannot be used when writing performance or behavioral objectives. We suggest that terms such as these be used in specifying goals or intermediate objectives. Remember that you make the decisions about the kind of performance you think is most appropriate or relevant to a selected grade level or age group.

Thus, the first and most important element of any performance objective is the stating of the action verb and its attendant objective. In many cases, this is the main performance objective. However, according to Robert F. Mager (1962), the exponent of the performance objective movement, there must be two additional elements to make a performance objective truly communicative: the conditions under which the performance is to take place and the evaluative statement.

Element Two: Elaboration of the Conditions

The second element in the prescribing of a behavioral objective is the statement of the *conditions* under which the learner is to perform the behavior. If location is important to accomplishing the objective then this must be stated in the conditional element of the objective. This decision establishes the circumstances or conditions under which the learner must perform the action. Generally conditional elements refer to:

1. What materials may be used to do the tasks.
2. How the performance may be accomplished, for example, from memory, from the textbook, or from a handout.
3. Time elements (although time may also be used in evaluation).
4. Location of the performance (in the classroom, at a learning station in the library).

Observe this example: "With the aid of the Periodic Chart, the student will list the atomic weights of the first ten elements . . . ." Note that the conditional statement is "with the aid of the Periodic Chart." This tells a student that there is no need to memorize the atomic weights, but to be simply able to identify them from the Periodic Chart. We often refer to the conditional component of a performance objective as a "statement of givens": "Given this" or "given that," the learner will accomplish something.

Perhaps the conditional element of a performance objective is the "fair play" part of the instruction. How many times have you walked into a science class only to find that when the teacher said to "study" a lesson, the actual of implied meaning, at least according to the teacher, was to "memorize" the lesson? The imprecision of such conditions is confusing, if not demoralizing, to students and can often lead to discipline problems for the teacher. We recommend that this element of instruction always be given explicitly to students whether you use performance objectives or not.

Below is a list of a few conditional statements that could be included in the appropriate performance objectives.

1. "From memory . . ."
2. "Using a list of . . ."
3. "On a handout, which describes . . ."
4. "Given six different samples without labels . . ."
5. "From the notes taken while observing shadows . . ."
6. "Using all 10 blocks in the stack . . ."
7. "Within a 10-minute time span and from memory . . ."
8. "When given the names of six substances . . ."
9. "Using the Celsius thermometer . . ."

10. "With a compass, ruler, and protractor . . ."
11. Using a magnet . . ."
12. "Using the three chemicals and glassware provided in the tray . . ."
13. "Using an overhead projector . . ."
14. "Given a set of data . . ."
15. "With the use of litmus paper . . ."

These are some general examples of the conditions under which a student can achieve a desired science performance objective. In most cases, the condition will be singular and simple, e.g., from memory; however, the condition may be multiple in nature. The conditional statement is set by the teacher and given to the learners in advance. We recommend that the condition be written as the first component of the performance objective, although its placement is not a major issue over which to argue. We simply view it as having greater impact on the teacher, so that it is not omitted. In addition, conditions must be realistic. Even though technically prescribed, "Listing 96 chemical elements in alphabetical order from memory in 10 minutes" would be a most irrelevant condition and stupid assignment. One must always ask, "What is my main priority for the objective?" If memorizing is the priority, then that condition will effect the attainment of the objective. If identifying 36 key elements on the Periodic Chart is the priority, then a condition less rigorous than memorization would be more compatible with the objective.

We highlight this point, not to be facetious, but to warn you of possible pitfalls. In our collective experiences, we have witnessed performance objectives with outrageous, if not impossible, conditions. Conditions must not act as an unreasonable impediment to the student responding to the essence of the objective in an effective manner.

Element Three: The Criterion Measure

Perhaps the most unique element and the most difficult decision to be made in a three-part performance objective is the definition of an acceptable standard of performance. This standard is usually called the "criterion measure," "level of performance," "minimum criterion," or the "minimum acceptable performance." Whatever the term used to define this element, it must be kept in mind that the designated level is the minimum or lowest level of acceptable performance. Traditionally, this level is indicated by a grade of "C" the average level. With this truly unique element in instruction, a student knows in advance exactly what the standards are by which the work will be judged.

Examine the selected criterion measures, remembering that the condition and the performance verb are missing from the statements.

1. ". . . 70 percent of a given list of problems."
2. ". . . within 2mm. . . ."
3. ". . . 9 out of 10 of the elements . . . ."
4. ". . . within five minutes, with no more than two errors of any kind."
5. ". . . the project will be compared to the two models illustrated by the instructor."
6. ". . . without any grammatical or spelling errors."
7. ". . . containing one dependent and one independent variable."
8. ". . . in exact order from the Sun to Pluto."
9. ". . . in 10.0 seconds or less."
10. ". . . 8 out of 10 consecutive trials."

Each of these criterion elements illustrates a well defined standard toward which the student could strive. These standards are always devised so that the students have a high probability of achieving them and thus will be encouraged to continue to achieve the established criterion. We also caution that many teachers expect far too much from their students and set standards that are too high or impossible to reach. You must know at what level your students are working so that you may establish "reasonable" minimum standards, an accomplishment that is both an art and a science!

Frequently an instructor will require 100 percent of the class to attain 100 percent of the objective, that is, complete mastery. Such criterion measures are called 100/100 criterion measures, since 100 percent of the class must obtain a 100 percent score. There are many times when teaching science that you will require mastery, such as when building skills, applying knowledge, constructing something, using equipment, stressing safety procedures, and doing other basic activities. In these cases mastery or the top level is the minimum acceptable level. Again, you, the professional, must make that decision. When completing prerequisite or entry-level tasks, the mastery criterion is most appropriate, since later skills are contingent on performing the initial ones.

Criterion grading

A word of caution must be expressed about criterion levels. Far too frequently, a percent number of a time is prescribed by the teacher as establishing the evaluation element of the performance objective. If time is a critical factor in the real world, in brake-reaction times, and manipulating machinery, then a timed criterion is appropriate. But to set the time of early or initial science experiences identical to that of practitioners in the field is _inappropriate professional behavior on the teacher's part_. Science skills and processes can be built or improved by using variable criterion measures just as with any systematic method aimed at improving skills. Thus, a criterion measure of 30 seconds for a skill in the first experience may be reduced as the learners improve. Typing teachers have observed this principle in action many times. As time progresses in the course, the students are allowed fewer mistakes per selected time period. In short, the standards for an "A" or top grade or even a "C" or average grade are shifted to higher levels of achievement as the course progresses.

Science educators have criticized performance objectives for seeming to force them into giving "A" grades for minimum student performance. This need not be the case. As a teacher, you may write performance objectives with clear criterion measures and make the meeting of those objectives worth any letter grade you choose. You may establish the standard that the meeting of criterion measures in your objectives will earn your students a "C" grade. Not meeting the criterion measures in your objectives will earn students a grade of less than "C" and achieving a grade higher than "C" will require performance beyond those prescribed in your objectives.

Several other alternatives concerning performance objectives and grades are available to the teacher. You may choose to write several performance objectives for a sequence of science instruction. Each objective can be progressively more difficult, with each worth a higher letter grade. Thus, completing performance objective 1 is worth a grade of "D", while completing it and objective 2 is worth a grade of "C," and so on.

Another alternative, a variation on the one above, is to prepare performance objectives that have several progressively more demanding criterion measures. In this instance, each criterion measure represents a higher letter grade when the learner improves enough to achieve it.

Rather than pressuring the teacher into giving a high grade for mediocre science performance, careful use of performance objectives gives the teacher the ability to prescribe precisely the value and meaning of letter grades in terms of overt learner performance.

To be complete, performance objectives must have criterion measures. But, there are circumstances in which the criterion measures may not appear in the performance objectives themselves. One such situation is when the teacher has established a class norm that holds true for all similar objectives given to the class. For example, a teacher may set a standard requiring that all readings on a thermometer must be read within 1/2 degree Celsius. All of the performance objectives for the instructional sequence are presumed to include this criterion measure. In another example, a teacher, at the beginning of the school year, establishes the norm that all written assignments must be without error in spelling and punctuation. Although subsequent performance objectives for the class may not have this criterion measure explicitly stated, it becomes, in fact, a part of the criterion measure in each performance objective requiring written work.

Perhaps the establishment of reasonable levels of excellence is the most difficult task in writing a three-element performance objective. It certainly is the part that requires teacher decisions that reflect discretion and fairness. Determining whether the criterion level demanded of the student is valid, in terms of the purposes of instruction, is a critical decision for the responsible teacher who prepares performance objectives.

Finally, what becomes of the students who cannot measure up to minimum standards? Are they simply flunked? For the time being, we leave that question for you to ponder with your peers.

Models of Completed Performance Objectives

Below is a series of performance objectives that contain the three elements described in this chapter. As you read each objective, identify each element; then compare your analyses with those of your laboratory small group.

1. Given a list of titles of 10 chemical formulae, the learner must identify in

writing the four that contain Calcium.

2. From those alternatives discussed and listed in this class, the student from memory, must list three of the apparent causes of the ban of DDT.
3. Using the data generated by the class in the experiment, the student will list three conclusions which can be validated by the data.
4. Using red litmus paper, the student will test the 10 liquids and identify the five which are basic.
5. Using the description of an ecosystem, the student will identify in writing the three subsystems, with complete accuracy.
6. Given a compass, a battery and a wire, the student will demonstrate that a magnetic field may be induced in the system. The student must provide evidence that others could replicate.
7. After completing the chapter on environmental issues, the student will list at least six problems that could become issues in your own city.

8. Given a completed series circuit and a switch, insert the switch so that it will close or break the circuit. This task must be completed in two minutes.
9. Using your own criteria, identify five "greatest" twentieth-century science discoveries. Identify at least two outside sources or writers who agree with your selection. The paper is due in one week and must be at least 300 words in length.
10. Given a set of metallic and nonmetallic objects, list a method that can be used to distinguish the objects from each other, i.e., all metallic from all nonmetallic.

Are Performance Objectives Necessary?

The establishing of behavioral objectives is not an educational panacea that will resolve all learning problems. It must be emphasized that there are limited purposes for writing performance or behavioral objectives. Behavioral objectives are only a means to an end per se. The purpose of the objective is to communicate the exact intent of the science lesson, the behavioral objective being one component of the lesson plan. A teacher can construct technically correct objectives but can fail completely in the classroom because of a lack of teaching skills and interpersonal competencies or strategies.

When developing lessons that use behavioral objectives, a teacher must accept the following assumptions:

1. Learning is defined as a change in the learner's observable behavior.

2. Behavioral changes are observable in some form and may be measured by appropriate measuring devices over a specified period of time.

3. Observed learner outcome is primary to the teaching strategies, the content, or the media used.

4. The vast majority of all children at all ages can master any subject at some acceptable level if they are given enough time and adequate, appropriate learning experiences.

Problems in Writing Appropriate Objectives

We have noticed at least four major problems that teachers encounter when writing behavioral objectives. Each of these four is discussed below.

Confusing Instruction with the Conditional Statement

One of the common traps into which teachers fall is that of writing a behavioral objective that is nothing more than the condition under which the instruction is to take place. For example, written objectives that state, "After viewing a film" or "after classroom safety instruction," are statements referring to the conditions that should take place prior to the performance. They are *not* performance conditions or objectives. Thus, we have found that teachers confuse what they intend to instruct with what they want the learner to learn by specifying *prerequisite* conditions. More appropriately written conditions may specify "from memory" or "using classroom notes taken while viewing a movie" when the student is to recall a concept or a set of concepts.

Incomplete Criterion Statements

In developing the criterion statement for an objective, it is very easy to make a statement such as "define" 8 out of 10 terms," which specifies only the quantity of the performance but not the quality. In such a case, the instructor must first have a set of criteria by which to judge the quality of each definition before determining whether the student has given the minimum number of eight definitions.

Level of Performance in Criterion Statement

For a long time our society has accepted a graded level of performance: 70 percent = C, 80 percent = B, 90 percent = A, and so on. Using the behavioral-objective approach to teaching requires a different system of grading, because the criterion level is related to the performance. A teacher must ask two questions: (1) "At what level must my students perform in order to be successful in subsequent science tasks?" and (2) "What level is considered successful in the world in which the student lives?" In a beginning science class, the teacher strives for a 95 percent to 100 percent mastery of concepts, while in a beginning archery course, the instructor considers an acceptable level to be 50 percent of the arrows hitting the target. At best, the teacher establishes a hypothetically acceptable level of performance and keeps collecting data to substantiate, modify, or reject that level. Remember, that in nearly all cases standards are subjective, if not arbitrary!

Another problem related to the establishment of minimal levels of performance is the tendency to convert all levels to percentage scores. "List an operational definition that is 80 percent correct" is a misuse of a criterion measure and is inappropriate. A more reasonable approach would be to define operationally the elements necessary for an acceptable statement. Once the attributes or elements are stated, it may be reasonable to request a certain percentage of these attributes or elements to be included. For example, the criterion that "each experiment must have one controlled variable" provides a valid standard by which to judge an experiment.

Still another problem is the overuse of time statements within the criterion measure. By placing time in the statement, the instructor is suggesting that time is at least as important as is quality, and even more important, if the quality criterion is omitted from the objective. Putting a time limit on science activities that require manipulation or constructed products usually defeats the intended outcome such as *accurate writing* or *accurate construction*. The decision to include time must be deliberate and not just a habit developed by a clock-watching teacher.

Reductio ad Absurdum

Given these three Latin words, the student will copy exactly the definition of this term from Webster's Collegiate Dictionary.

We assume that at this point you have asked yourself, "Couldn't all this performance-objective writing lead to compilations of millions of trite, useless, and seldom used lesson plans?" And the answer is "And How!" Advocates of performance objectives sometimes fail to caution that you can fall easily into the trap of working out mechanistically a series of performance objectives that are totally and irrevocably irrelevant.

If you make the decision to use this instructional technique in the science class (or if someone with higher authority makes the decision for you), then you must be careful not to generate trite, redundant lists. We have seen science teachers who hand their students pages of performance objectives and simply tell them that they are on their own--all in the name of individualized instruction. Furthermore, we have witnessed the publication of thousands of objectives that are on exchange so that teachers can borrow from each other. We have also heard discussions in which teachers find themselves trying to prescribe every single learner activity with such specificity that the objectives, not the learner's achievement of them, become all important.

In short, we are cautioning that overuse of performance objectives is just as absurd as not using any at all. Your decision to use them must always be predicated on the potential benefit to the learner.

Reasons for Using Behavioral Objectives: Summary

Behavioral objectives clarify the intent of the science lesson for the teacher. With clearly stated outcomes in mind, the teacher is better able to design appropriate learning experiences for the class, and for each child, if the program is individualized or computerized.

Behavioral objectives also clarify the intent of the lesson for the learner. The student is able to use time more efficiently, since he or she has the knowledge of what is to be performed. If the approach is employed in a self-instructional program, the student may have the alternative of individually selecting science learning experiences.

Behavioral objectives make it easier to measure student achievement. Since the criteria are stated in the objective, both student and teacher know what is expected of the student, and the student gets immediate feedback about the performance. It is simpler to arbitrarily assign students an A, B, C, or F without specifying what it is that is being measured. You may recall those extremely biased essay tests in which no learner objectives or grading criteria were specified.

A teacher may still assign A's, B's, and F's, but only with a prior explanation of the criteria by which such grading standards will be applied. Also, by specifying behavioral objectives, a contract grading system may be developed, or a different qualitative component may be prescribed, for each different level of performance for each grade.

Behavioral objectives make it easier to measure effectiveness of instruction. The teacher's job is to aid student learning. Since the level of performance is stated, it is easier to determine if the selected materials, activities, and teaching strategies have been helpful to the student in achieving the stated objectives. As a result, effectiveness of instruction is based on student achievement of the instructional objectives.

Behavioral objectives should help to develop a more effective communication system among teachers, students, administrators, and parents. A well stated set of behavioral objectives provides a common frame of reference for discussion. Since instruction is the primary purpose of education, precisely written instructional objectives are essential to any meaningful deliberation.

Reginald F. Milton (1978) reviewed the research concerning the effect of behavioral objectives on student learning. He noted that the findings of reported research are very conflicting. However, there do seem to be several generalizations that are supported by some research evidence.

1. Behavioral objectives do act as guides to student learning and as advance organizers.

2. Performance objectives tend to depress incidental learning.

3. Providing students with behavioral objectives after a learning sequence tends to improve incidental learning.

4. Distributing performance objectives throughout the textual material may improve learning, that is,

distributing the objectives over an assignment may be more effective than giving all the objectives at once.

A Final Caution

Specifying learning activities in behavioral form is just one element in the totality of teaching science. A teacher who uses appropriately designed behavioral objectives may develop into a better instructor. A disorganized, haphazard, or slovenly teacher with or without behavioral objectives will still be disorganized, haphazard, or slovenly. But more importantly, the quality of the objectives is of prime importance. A teacher with technically correct and relevant objectives will help students to demonstrate more relevant science behaviors.

One last caution. We advocate hands-on activities and inquiry as two absolutely essential attributes of good science teaching. We have found out that it is very difficult if not impractical to write performance objectives that are inquiry oriented. The concept of inquiry is antithetical to performance objectives. It is important to realize that point.

Further, we really do not accept the assumption on which behavioral objectives are predicated. If learning is only observable behavior then most of what is important to humankind is not learned-- trust, initiative, care, persistence. Donald C. Orlich even doubts that the evidence supporting behavioral objectives is empirically validated. In short, some outstanding science teachers never use behavioral objectives. Yet, this instructional technology is blindly followed in the field. So, we must address it or be out of touch with practice--even if bad practice.

Behavioral objectives are no panacea for the ills of science. But if you wish to be more precise in delineating science learning outcomes, then performance objectives ought to help in making the learning goals more sharply focused. It is your decision how to use this technique correctly.

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CHAPTER 3

TAXONOMIES AND TEACHING SCIENCE

The concept that underlies all educational taxonomies as decision-making tools is simply this: Not all teacher or student behaviors are the same. Accordingly, different responses are elicited from the student. That is, if the teacher acts differently, the student will respond in different ways. From this, we may infer that the student is learning different behaviors. Taxonomies are classification tools that science teachers use to describe the quality of different learning outcomes.

Teachers may be identified by the different actions they perform. These actions may include the formulating of performance objectives, of questions to be asked, or of tests to be administered. Within these clusters of teacher behaviors (performance objectives, questions, or tests), not all actions are the same. Teachers can generate different objectives, ask different questions, and formulate different tests on basically the same topic or content. These different objectives, questions, or tests reflect differences in the teachers' goals. For example, there is a great difference between the question. "When did Einstein discover Relativity?" and "How did Einstein's discovery of relativity affect physics?" One way of examining and comparing the differences in teacher emphasis is to analyze these teacher behaviors in terms of a taxonomy. A taxonomy is a classification system that educators use to observe, compare, and evaluate performance objectives, questions, written materials, and evaluation methodologies (tests).

As stated previously, a taxonomy is first a classification system, a way of grouping selected objects together, such as plants, animals, performance objectives, or questions. We consider a taxonomy to be more than just a classification system. What differentiates a taxonomy from a classification system is that a taxonomy assumes to be hierarchical in characteristic; that is, a taxonomy is a classification system with a prioritizing or ordering. Not all the classes of learning are at the same level. The method by which the classes are arranged in a hierarchy depends upon the organizing principle and the type of taxonomy.

In the taxonomy of the animal kingdom, the phyla are arranged according to evolutionary complexity.

Thus the phylum Chordata (animals with backbones) is higher than Porifera (sponges), which is higher than Protozoa (one-celled animals). In most educational taxonomies, the organizing principle is that of intellectual complexity. The higher levels in taxonomies involve more complex student behaviors than the lower levels. In addition, the higher levels in taxonomies build upon the lower levels. If a student can perform at a third level, then we also assume that the student can perform at the two lower levels. This subject will be discussed further later.

Using Taxonomies in Science

In teaching science, the formulated objectives should determine the teaching procedures and the evaluation procedures, but with all elements affecting each other. A taxonomy can be used in each of these processes: (a) in formulating objectives at an appropriate level; (b) in developing classroom questions and learning exercises; and (c) in constructing evaluation instruments that are congruent with the objectives and strategies previously employed. In other words, taxonomies can be used to decide what to teach, how to teach, and how to evaluate the effectiveness of our teaching.

Why Use a Taxonomy?

For any educational tool to be useful, it must be regarded as appropriate and effective. Science teachers employing taxonomies have found them to be useful because they serve the following purposes. (You may want to add your suggestions to this list.)

1. Provide a range of objectives. A taxonomy provides a list of possible ranges of objectives available by which to teach science. A close examination of the categories may prevent the teacher from overemphasizing one level, such as the knowledge level, in his or her teaching. In this respect, a taxonomy not only adds variety to the teacher's repertoire but also gives greater breadth to his or her science objectives.

2. Sequence objectives. An analysis of learning tasks will indicate to the teacher the learning experiences necessary for the student to obtain the intended outcomes. A taxonomy provides one means of sequencing learning, from simple to complex interactions.

3. Individualize instruction. Related to the idea of sequencing instruction is the use of taxonomies as tools for individualizing instruction. Several recent developments in education make this an especially persuasive argument for using taxonomies. One such development is the growing realization on the part of educators that there is a great deal of heterogeneity in most classrooms. Students not only enter classrooms with different experiential and knowledge backgrounds, but also learn at different rates and in different optimal situations. This problem of heterogeneity is further complicated by the mainstreaming of some special education students into the regular classroom. By identifying and sequencing a number of learning objectives and activities in terms of a taxonomy, the teacher allows the students with differing capabilities to start at different points in series of learning objectives and to proceed through the sequenced activities at different rates, hopefully achieving higher levels of the taxonomy.

4. Reinforce learning. Since each lower category of the taxonomy is subsumed by the next higher category, reinforcement of previous learning occurs if learning experiences are sequenced in terms of a taxonomy.

5. **Provide a cognitive structure**. Researchers have shown that students learn and retain information better if it is organized into some type of cognitive structure rather than presented as isolated items. Taxonomies can provide a cognitive structure to teachers by helping them evolve from facts to comprehension, application, analysis, synthesis, and evaluation of ideas, concepts or operations.

6. **Insure instructional congruency**. Once a science objective (or concept) is written and classified by the teacher at a particular level, it helps the teacher in selecting the most appropriate teaching strategies and evaluation techniques that coincide with the level of the objective. If an objective is written at the application level, learning experiences for students must be provided where students apply the knowledge. In addition, the student should be tested or evaluated at the level at which they learned. If the goal of a particular science unit is to teach a person how to control variables, then the teaching activities should be geared toward this goal and the evaluation should match. In this situation, a

paper-and-pencil test would be congruent with the learned behavior. The teacher can prevent mismatches by analyzing his or her objectives, learning activities, and evaluation procedures, making sure they are compatible with the science objective or activity.

7. **Diagnose learning problems**. Should a student not achieve the intended outcome at the level specified by the teacher, the teacher can systematically examine at which level the student is encountering the learning difficulty and thereby prescribe learning experiences to help the student overcome the specific learning deficit. This use of taxonomies may become increasingly important in view of the growing acceptance and retention in our schools of students with diverse cultural backgrounds, as well as the mainstreaming of special education students into the "regular" classroom.

8. **Provide a learning model**. By experiencing a series of "hands-on" learning activities sequenced in terms of a taxonomy, students are able to perceive that science can be sequenced according to the relationships of the categories to each other, thus obtaining a model of learning that they too can use when they leave the classroom.

9. Design appropriate test items. Teachers who understand the principle of fairness will be quick to use the taxonomy as a self-evaluation device to check the appropriateness of test items. There is evidence to show that most teachers at most levels of instruction teach at rather low levels. Yet tests are often constructed to measure higher levels of thinking. This is not fair to the students. The teacher can match learning objectives and teaching activities with the test items to determine whether or not the test approximates the level described in the objective and at which the lesson was taught. This is an application of the concept of congruency.

10. Assist in instructional decision-making. By using a systematic method of analysis, teachers can decide where the learning will lead and how much time to devote to establishing meaningful prerequisite skills. The taxonomy thus acts as an instructional guide for the teacher.

We are now ready to begin an analysis of the taxonomy of the cognitive domain.

Bloom's Taxonomy: A Classification* System For The Cognitive Domain

Educators have divided the types of learning that take place in the schools into three areas: affective, psychomotor, and cognitive domains. The affective domain deals with attitudes, interests, and values. The psychomotor domain deals with manipulative or motor-skill activities (for example, printing, writing, or mixing chemicals). The cognitive domain, the area with which we are primarily interested, concerns knowledge and the development of intellectual abilities and skills. Most of the time, teachers at both the elementary and secondary levels are concerned with the cognitive domain. The most widely used classification system for analyzing objectives in the cognitive domain is Bloom's Taxonomy. In 1956, Benjamin S. Bloom, co-edited a book entitled _Taxonomy of Educational Objectives: Cognitive Domain_. Thus we commonly refer to this classification system as Bloom's Taxonomy. Bloom's Taxonomy classifies cognitive behaviors into six categories ranging from fairly simple to more complex behavior. A brief description of these categories can be found in Table 4-1.

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TABLE 4-1 Six Major Levels of Bloom's Taxonomy

Level	Characteristic Student Behaviors
Knowledge	Remembering; memorizing; recognizing, recalling
Comprehension	Interpreting; translating from one medium to another; describing in one's own words
Application	Problem-solving; applying information to produce some result
Analysis	Breaking something down to show how it is put together; finding the underlying structure of a communication; identifying motives
Synthesis	Creating a unique, original product that may be in verbal form or may be a physical object
Evaluation	Making value decisions about issues; resolving controversies or differences of opinion

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Like other taxonomies, Bloom's Taxonomy is assumed to be hierarchical, with learnings at higher levels being dependent upon the attainment of prerequisite knowledge and skills at lower levels. These features of the Taxonomy will be discussed and illustrated in the text that follows. We will begin our discussion of the Taxonomy with a description of the first level--knowledge.

Knowledge

Knowledge is the category that emphasizes remembering--either by recall or recognition. An example of a recall operation is a fill-in-the-blank exercise and an example of a recognition operation is a multiple-choice exercise requiring the recall of information previously encountered. Both of these processes involve the retrieving of information or facts that are stored in the mind. For the most part, the information retrieved is basically in the same form as it was stored.

For example, if an elementary science teacher teaches the students on one day that Stanford University is the site of the world's longest linear accelerator, then an appropriate Knowledge-level question to ask on the next day would be "What is the site of the world's longest linear accelerator?" In answering this question, the student would be attempting to remember the knowledge in basically the same form as it was learned. Other situations involving Knowledge-level activities include memorizing data, remembering the steps to follow in making a chemical test, and answering true-false and matching questions on a test.

Knowledge-level objectives have as their primary focus the storage and retrieval of information. In answering a Knowledge-level question, the student must find the appropriate signals in the problem that will most effectively recall the relevant knowledge stored. In the Knowledge category, the student is not expected to transform or manipulate knowledge but merely to remember it in the same for as it was presented.

Knowledge-level activities may consist of:

1. Recall of specific facts or bits of information (for example, What is the speed of light?).

2. Recall of terminology or definitions (for example, What is a proton?).

3. Recall of conventions or rules of usage (for example, How do we graph rate/time/distance problems?).

Teachers generally recognize that the Knowledge category forms the basis for the other categories. In fact, teachers overuse this category. Studies have indicated that the majority of science teachers (and textbooks) formulate most of their questions (both in class and on tests) at the Knowledge level.

Consequently the thought processes of the students (and the teachers) are kept at very low levels. Perhaps this is why so many young people find science to be boring and nonchallenging. But, science does require the knowing of it before it can be used more creatively.

Comprehension

The Comprehension category emphasizes the transforming of information into more understandable terms. Like all categories above the Knowledge level, the Comprehension category is used to emphasize ways of handling information that has already been stored. Comprehension activities require students to demonstrate an understanding of the material through some type of manipulation or altering of the material before answering a question. The distinction between manipulation and recall is important. Knowledge-level questions require recognition or recall by the student ("Where have I heard or seen that before?"). Comprehension-level questions require the student to assemble various ideas and modify them in some way before giving an answer. The comprehension or understanding may be evidenced by oral, written, pictorial, or concrete presentations.

The basic idea behind the Comprehension category is to get students to understand the material and not just to memorize it. This active attempt to understand material thus makes this category one step higher than Knowledge. (An example of the difference between the two would be the difference between reciting the Carbon Dioxide Cycle and understanding what the words mean.) However, unlike some of the higher categories, the Comprehension level does not ask students to extend information but merely to integrate it into their own frame of reference.

A Comprehension-level question requires a greater degree of active participation by the student. In responding to a Comprehension-level question, the student must somehow process or manipulate the response so as to make it more than simple recall. This distinction is important from a learning-theory point of view. That is, material that students rephrase into their own words, or that they organize to "make sense" personally, will likely be learned more quickly and retained longer.

While it might seem that the comprehension level is one simple step "up" from the knowledge level, it must be realized that the step is a very large one.

Raymond S. Nickerson (1985) presents persuasive evidence that to master physical sciences concepts, it is understanding that separates those who truly master physical science and those who do not. Understanding may be the key to all other elements of the cognitive taxonomy. If we accept Nickerson's premise, then science teaching in the elementary school must strive for pupil understanding. This has great implications when one considers that on a national level science is virtually "read" with little if any hands-on experiences provided. Much of the content in elementary school science is presented to know, not to understand. To understand science, the pupil must be allowed to interact with the concepts and apply them. You cannot teach three or four science concepts per day, as is the case in nearly all leading textbooks now in print.

Below is a mixture of science learning objectives and questions, written at the comprehension level.

1. Compare the metric and English systems of measuring temperatures.

2. What similarities are there in the metric and English systems of measuring temperature?

3. Compare chemistry as we know it now to its early roots of Alchemy.

4. What differences exist between density and mass?

5. Describe orally in your own words what an ion is.

6. List your laboratory findings in a table, then write a short summary of what the data mean.

7. List three common household acids and three bases.

8. Name two subsystems of the larger biotic system.

9. Describe the kinetic theory in your own words.

10. Give an example of relativity that can be observed while riding in a moving vehicle.

Application

The application category, as the name implies, involves using information to arrive at a solution to a problem. In operating at the Application level, the student typically is given a problem that is new to him or her and must apply the appropriate principle (method of solving the problem) without having to be prompted regarding how to resolve the problem. Also, the student must know how to use the proper method once it has been chosen. When the teacher evaluates an Application problem, he or she should check both the solution and the process. Both of these are important subcomponents in the Application-level problem. If the problem has been gone over the day before in class, the task for the student would involve mere recall, thus making it a Knowledge-level activity.

Operations at the Application level can be visualized as a two-step process. In the first step of the process, the student encounters a problem that he or she has not seen before and recognizes it as a subset or type of problem solved before. Note that we have used the words subset and type rather than same with the problem encountered before. The novelty or originality of the problem is an essential characteristic of an Application-level problem.

During the second step of solving an Application-level problem, the student selects an appropriate solution and applies it to the data at hand. This solution can consist of an algorithm, a formula, an equation, a recipe, or a standardized set of procedures for handling a specific type of problem. Examples of the Application level follow.

The formula for density is weight (or mass) divided by a unit volume, or D = M/V . At the knowledge level, the student would simply recite the formula. At the comprehension level, students could be asked to put the formula into their own words. To determine if students are at the application level, a teacher would provide data about materials and require that students compute these data in the correct format. The data would be new to the student.

One may ask, "Is this not simply comprehension?" No, because the students are going beyond a basic understanding. For example, to solve a density problem, a student might have to understand eight separate concepts or tasks (weighing, measuring, computing two dimensional and three dimensional measurements, computing volumes, defining the standard unit of measure, using data correctly and solving the problem.) To apply the formula correctly is comprehension. To work it with data seems to meet the criteria for application.

When students assemble or create scientific models to be a replica of the "real thing," they are applying knowledge.

A few examples of performance objectives written at the application level follow:

1. Detect evidence of interacting systems.

2. Predict the relative rates that the gears will turn by using interacting wheels.

3. Interpret the dissolving of a material in a liquid.

4. Predict objects that will interact at a distance.

5. Create a relative motion illusion by constructing a "flip book."

6. Determine the variable of quantity of salt needed in a solution to hatch brine shrimp eggs.

7. Make a simple limb graft on a tree.

8. Predict whether or not there will be a change in the developmental sequence of tadpole eggs.

9. State on hypothesis about the relationship of lengths of pendulums to their swing--amplitude.

Analysis

Application involved the bringing together of separate components to arrive at a solution. Analysis involves the converse of this process in that complex items--such as systems, written communications, organizational patterns, or machines--are taken apart and the underlying organization behind them is explained. The emphasis in Analysis-level operations is on explicating how the various parts of a complex process or object are arranged and work together to achieve a certain effect. Another common kind of Analysis question offers an example of reasoning and asks the student to judge whether or not it is logical. Yet another type of Analysis question asks the student to discover the personal motives behind a communication.

Analysis is probably most related to the Comprehension and Evaluation categories. Comprehension involved finding similarities and differences and making comparisons. Basically the task at that level was to show relationships that could be discovered by understanding the communication itself. Analysis, however, goes beyond understanding a communication and involves being able to "look beneath the surface" and discovering how different parts interact. In this sense, Analysis builds upon Comprehension, but goes beyond it. Analysis involves working backwards, taking a situation or event and explaining how all the parts fit together to give a total effect; Comprehension, on the other hand, primarily involves describing what that effect is.

Some science analysis activities follow:

1. After listening to a debate on evolution vs. creationism, the student will identify the differences in major research evidence presented by each proponent.

2. Given a model of an ecosystem, the student will explain the relationship between two subsystems.

3. What are the implications of genetic engineering?

4. Why did the USA build the first nuclear bomb?

5. List the unstated assumptions in the ionic theory.

6. Distinguish the facts, and assumptions from the hypotheses in the evolution arguments.

7. How do pulleys and simple levers relate to each other?

8. Given a set of 20 different leaves, design a pattern that would encompass all their shapes.

9. How does plant adaptation lead to change.

10. Given a "dye" solution, determine the number of separate colors in it by using a chromatography technique.

Synthesis

A Synthesis-level operation entails the creative meshing of elements so as to form a unique new entity. Because of the emphasis on creativity, the Synthesis category may be the most distinctive and one of the easiest to recognize. Synthesis is the process of combining parts in such a way as to constitute a pattern or structure that did not exist before. A research paper can belong to either the Application or Synthesis category, depending upon the level of originality. If the paper is comprehensive and thorough but does not add anything to the topic that is not already there, we consider the writer to be operating at the Application level. However, if the writer puts ideas together in new or unique patterns or creates new idea configurations, then we consider this to be a Synthesis-level activity.

This category probably stimulates the most creative behavior. In fact, by definition, the Synthesis category requires the creation of something unique, a product of the individual and his or her unique experiences. Consequently, the whole of the creation is more than just the sum of its parts; the parts are held together in a unique combination--the whole. This is not to say that every Synthesis operation must be a work of art. A second grader writing a poem can be working at the Synthesis level. What is important in this case is that the second grader is translating a unique experience into poetic expression.

Because the emphasis is on creativity, operations at the Synthesis level are usually difficult to grade objectively. Thus the teacher must use more subjective judgment in evaluating Synthesis operations. The teacher must also be cautious about stifling creativity. Maximum leeway should be allowed for creative expression if creativity is to be encouraged.

Benjamin S. Bloom et al. (1956) differentiate the various subcategories of Synthesis according to product. In one subcategory, the product or performance is a unique type of communication. An experiment is an example of this subcategory. Here the scientist is trying to communicate certain ideas and experiences to others and does this through the selected techniques. Typically, he or she is trying to perform one of the following functions: to inform, to describe, to persuade. In doing this, a scientist is attempting to achieve a given effect. The particular experiment used, together with its forms and conventions, is selected to convey certain ideas and experiences optimally. The product or outcome of the Synthesis operation can be considered unique in at least two respects. First, the author has considerable flexibility in communicating the idea and uses this flexibility to create a product unlike any others. Secondly, the product is evaluated partially according to its uniqueness; thus, students are encouraged to add their own personal contributions to the product.

The second subcategory of the Synthesis level involves the developing of a plan or proposed set of operations to be performed. Bloom et al. illustrate this subcategory in Table 3-2. Note that all of these operations result in the creation of a tangible product. This tangible product and the quality of it may be judged independently.

TABLE 3-2 Synthesis Operations Involving the Development of a Plan

Proposed Set of Operations	Process--i.e., carrying out the set of operations	Expected Outcome
Plan for an experiment	Carrying out the experiment	Experimental findings; probability statement
A teaching unit	Teaching	Changes in behavior
Specifications for a new house	Building the house	The house

Examples of Synthesis objectives for science follow:

1. Propose models to explain selected observations of simple electrical systems.

2. Using a magnet, iron filings, and a piece of paper, create evidence that a magnetic field exists.

3. Using a collection of 20 different buttons, create a taxonomy that will allow each to be individually categorized. (Could also be comprehension or application.)

4. Devise two ways to test the hypothesis suggested in the text.

5. Given a set of data, observations and techniques, prepare an hypothesis to explain the results. (Could be analysis.)

6. Evaluate a proposed model by interpreting the provided evidence, making predictions and suggesting experiments to test the predictions.

7. Verify the hypotheses about the gases that plants produce and use.

8. Predict the amount of ice that will be melted by water of a specified temperature. (Could be comprehension, application or analysis.)

Evaluation

The Evaluation category involves making decisions on controversial topics and substantiating these decisions with sound reasons. Creativity is to Synthesis as judgment is to Evaluation. Evaluation questions ask the students to state what they think and what their opinions and judgments are and to give the criteria on which these thoughts, opinions, and judgments are based. Evaluation involves the use of standards for appraising the extent to which particulars are accurate, effective, economical, or satisfying. To qualify for this category, the student must: (1) set up appropriate standards or values; and (2) determine how closely the idea or object meets these standards or values.

The Evaluation category projects the Analysis category into another dimension. In addition to analysis, an Evaluation question also requires that some type of value judgment be made. The criteria for judgment must be clearly stated and the quality of the Evaluation response should be graded according to how well the student has met the criteria. Because Evaluation is assumed to be the highest category in the Taxonomy, it demands the incorporation of all the other levels in responding to a situation or event. The Evaluation category requires the student to make reasonable judgments, to have rational opinions or personal reactions to a stimulus and to defend them in a logical and coherent fashion.

Though the Evaluation process is subjective to the extent that the student chooses the criteria, emphasis should still be placed on rational, well developed, rather than emotional, responses. This prepares the student for numerous situations in later life in which this type of response will be needed.

An Evaluation response should consist of two parts:

1. The student should establish criteria on which to base judgment.

2. Using the prescribed criteria, the student should make his or her judgment accordingly.

Examine the following five evaluation questions or statements.

1. To what extent should the United States spend most of its energy research dollars on solar or alternative sources of energy?

2. To what extent should the United States relax its clean air standards to stimulate employment?

3. As the United States develops new drugs, medicines and food production techniques, we should keep them secrets so that the rest of the world will rely on our scientific leadership.

4. Our environmental concerns are causing the United States to lose its productive capacity to other nations in the world.

5. Creationism should be given equal textbook treatment with evolution in all school textbooks.

Note that in each of the above there is some subjective or even creative element associated with evaluation. The critical point for science teaching is to stress the criteria by which the judgment is being made. Opinions are not valid without supporting evidence.

Quite obviously, values--personal, cultural, social--are all expressed through evaluation. For example, abortion is a medical technique. Yet, to some people this is not a medical issue, but a religious one. To others, abortion is a political or personal decision. More will be discussed about controversial science issues. What is critical now is that you know where these problems fall on the cognitive taxonomy.

The teacher should expect several different responses to the same Evaluation experience, because students have varying value orientations. For this reason, the teacher can use Evaluation questions to help students to learn to live with and accept the different views of others, thus preparing students for life in a pluralistic society.

Thus the teacher poses and Evaluation question by asking the student to take a stand on some issue. Questions such as "What do you think is best/worse more/most important?" serve to elicit Evaluation responses.

The Cognitive Taxonomy: A Critical Analysis

Bloom's Taxonomy has been used as an educational tool to analyze instructional practices since 1956, and an evaluation of the Taxonomy with respect to classroom use and other related research seems appropriate. Such an evaluation would point out not only the validations and uses of the Taxonomy but also its limitations.

On the positive side, the Taxonomy has gained nearly universal acceptance in the teaching profession and has proved to be a usable tool for science curriculum development and instructional and evaluative planning. On the negative side, studies have raised critical questions about the structure and organization of the Taxonomy, which have not been answered with either rebuttals or modifications.

The great majority of reported research studies on the Taxonomy involves articles advocating or illustrating the application of the Taxonomy in the classroom. The significance of such positive research and such encouraging articles is that they indicate a generally high level of awareness and acceptance of the Taxonomy by teachers. Because it was formulated by educators as an "educational-logical-psychological classification system," the Taxonomy has demonstrated great adaptability to many current educational practices.

Uses of the Taxonomy

The cognitive taxonomy has at least eight main uses by elementary science teachers.

1. Teachers can sequence their learning objectives and activities so that this is a gradual progression of intellectual and process skills.

2. Laboratory activities can be planned and used that reinforce the specified learning.

3. Standardized tests can be analyzed to determine their level of testing and how those levels compare to the tests given to children in various grades, especially in science and social studies.

4. Textbook content can be analyzed to determine the general intellectual levels being stressed by the authors.

5. Questions being asked by the teacher and students can be categorized using the six main levels of the taxonomy.

6. Programs that are designed for gifted students can be analyzed to determine at which levels most of the experiences are focused.

7. Complex scientific concepts can be subdivided for presentation so that students may progress through a series of cognitive processes.

8. Highly complex or difficult science concepts might simply be postponed for later years if the prerequisite skills are beyond the developmental level of the children.

Formulators of the Taxonomy hypothesized that different types of thought processes (transformations) occur in a student's head when asked "Who discovered nuclear chain reactions" than when asked "How would history have been changed if Germany in 1939 had discovered nuclear reactions rather than the United States?" The answers (products) given by students are different for each of the questions and reflect varying cognitive processes and require a great amount of knowledge. Obviously, this is inferential evidence, since we rally do not know what is going on in the brain.

Ask yourself this question: "How could my science classes be made better through the application of the principles presented in the taxonomies?" If you can become more systematic, analytical, and evaluative, then we have attained one of our goals.

It would be incorrect to conclude that all three Taxonomies have been totally validated. We really do not know if there is such a construct as a Taxonomy of

Life's Great Moments. What is important to teachers is that there are systematic methods by which to plan and structure the science activities that are most often associated with schooling. Knowledge of the existence of these Taxonomies allows for thoughtful and systematic science curriculum construction, which we believe would do much to improve instruction.

We readily conclude that far too many educators give only a cursory glance at the Taxonomies. Many teachers are unaware of their value, while others simply are uninterested in understanding the relationships that may exist in any cognitive area of study.

We submit that if the Taxonomies were applied to their optimal use, there would be far more cognitive success in the schools of the world; students would be more serious about their studies and would enjoy them more; and physical education would be supported for its own sake rather than considered merely an adjunct of athletics.

Our aim is to provide you with a better understanding of the decisions that are made by great teachers. By understanding the potentials of the Taxonomies, you will be adding one more tool to your "bag of professional skills," and probably improve science education along the way.

Post Script

Traditionally. science teachers are chided to raise the level of instruction above the knowledge level where virtually all teaching takes place. However, we submit that Nickerson (1985) has provided some evidence and a basic argument that illustrates the critical importance of stressing the comprehension or understanding level. Science is a conceptually organized discipline. In many cases, the concepts as determined by empirical testing do not logically fit into a child's scheme of reality. Even so, teachers tend to race through a textbook to finish it, without realizing that the students have a very fuzzy notion of what they have learned. Thus, if we want children to understand science, we must provide more time and concentration at this intellectual level.

Understanding precisely how a phenomenon takes place and under what conditions requires far more hands-on science than we in American schools are willing to devote. As was noted in Chapter 1, studies tend to show that science is taught less than one hour per week in early grades and perhaps as much as 90 minutes per week up to grades six or seven. We assert that it is impossible to teach for comprehension or understanding in all but a few basic concepts under that time constraint.

To apply knowledge of science takes more time. Thus, we submit that a major goal for elementary science should be focus on the levels of knowledge, comprehension and application in elementary science teaching. Japanese teachers will often spend several hours or even a full day to teach some concept to insure that children understand it.

This goes far beyond that horrid technique that is often observed when a teacher naively asks, "Is there anyone who doesn't understand?" Of course not, no self-respecting child will show ignorance by reaching for that bait. We condemn the above questioning technique. In its place we recommend actual drill or practice on questions where correct responses would indicate understanding, or better yet, use of activities to enhance and reinforce understanding.

Yes, this will take more time. Yes, we know that other subjects are being taught. But, if we are to provide significant educational experiences to youth, we must teach for understanding. Understanding a concept may even enhance student creativity in science. Adult problem solvers understand their fields and can easily apply principles. (Watch a mechanic who "trouble shoots" a problem with a car.)

Teaching to comprehension will have a high intellectual "pay off." Learners will enjoy science even more than current studies show, and we will encourage more adolescents in high school to enroll in more science courses.

As a nation, we need children who know how something happens and why. Instilling that habit of learning will pay great dividends in the future generation of knowledge and the advancement of the human condition. This is a critical challenge to all elementary teachers of science. But, it is one that must be met if science education is to add to the basic enculturation of our youth.

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CHAPTER 4

QUESTIONS AND TEACHING SCIENCE

The single most common teaching method employed in the schools of America and, for that matter, the world seems to be that of asking questions. It may have formally started with Socrates, but the practice still remains first on the list of teaching strategies of all scientists--and science teachers. Therefore, it is important for you to master the logic and application of questioning as you develop your capacity as a competent science educator.

Formulating Meaningful Questions

If you are to teach logically, then you must be cognitively aware of the process of framing questions so that student thought processes can be guided in a most skillful and meaningful manner. Implied is that you must design questions that help students attain the specific goals (i.e., performance objectives) of any particular lesson sequence. While textbook and examination questions contribute to the learning process, most questions that occur when teaching science are verbal and teacher formulated.

Although questioning is an important instructional strategy, it appears that teachers seemingly have mistaken the quantity of questions for quality. Researchers have reported that some teachers ask as many as 150 questions per class hour. To accomplish such a feat, most of the questions would have to be fact oriented (or very low level). While teachers stress that thinking is important, their questions do not reflect that emphasis.

There are several reasons teachers support the use of so many fact (low-level) questions. One rationale proposed by many teachers is that students need facts for high-order thinking. This is a cogent point, but there are additional ways to teach facts, such as computer-assisted instruction. Teachers also apparently overuse fact questions because they lack systematic training in the use of questioning strategies. The rush "back to basics movement" has caused curriculum material ro stress the lowest possible cognitive level--facts. Low level curriculum causes low level questions. Studies conducted by D.C. Orlich and colleagues revealed that when teachers are trained in questioning, the frequency with which higher-level questions are used in the classroom goes up significantly.

Another reason that teachers have tended to ask so many low-level questions is that, until recently, they have lacked an easy-to-use system to organize and classify questions. They have also lacked a means of evaluating the effect that different questioning techniques have on the learning process. This is where Bloom's Taxonomy (1956) can be of use. A majority of textbook authors use Bloom's Taxonomy to evaluate the potential for critical thinking in the classroom. This question classification system is based on the type of apparent cognitive process required to answer the question. Benjamin S. Bloom and associates use six cognitive categories to classify questions: knowledge, comprehension, application, analysis, synthesis, and evaluation. The thinking processes involved in this model progress from the simplest (knowledge) to the most complex (evaluation).

Each higher cognitive process probably includes all lower cognitive processes. For example, if a teacher asks an evaluation question, the student will normally use synthesis, analysis, application, comprehension, and knowledge to answer the question.

Again we caution: When building skills and concepts, you may have to devote large blocks of time to knowledge or level-one objectives and questions. But we urge that you then begin to build upward. If teachers emphasize low-level questions when it is high-level questions that stimulate thinking and evaluating, then we may have discovered one of the basic reasons why students find science boring.

Although the evidence is somewhat inconclusive, there does appear to be a direct relationship between the level of questions asked by the teacher and the level of student responses. Further, it appears that if a teacher decides to raise her or his expectations for the class and systematically raises her or his level of questioning, then students tend to raise the level of their responses accordingly. Of course, this implies a carefully planned questioning sequence that would probably span several weeks of instruction.

Tips for the Teacher

The implications of the above for teacher decision making are many. First, if you want your students to develop higher levels of thinking, to evaluate information, to achieve more, and to be more interested, you must learn to ask higher-level questions. Second, you must encourage your students to ask more questions, and more thought-provoking questions, if you desire greater student involvement in the process of learning. An example of one form that you can use to evaluate questions is shown in Figure 4-1. The form as presented is rather detailed, but you can abbreviate it so that it fits on a 3" x 5" card. The appropriate categories could be summarized on the card and then tallied as they are generated--in the classroom! Or you could tape-record a class session, and then tabulate the questions during a free period. After establishing a baseline rate, which would represent the percentages for the various categories during a specified science period, you could then devise a change strategy to improve any specific cognitive-skill-questioning area.

Another important implication for those of you who desire to stimulate critical thinking is that you should be aware of the advantages and disadvantages of your science textbooks and other printed materials. To obtain the objective desired, you will usually have to supplement the materials provided. One trick to use to develop student comprehension is to ask them to make up two questions about some passage in the science text or about the data that they collect in some related activity.

Category	Expected Cognitive Activity	Key Concepts Terms	Sample Phrases and Questions	Tally Column	% of Total Questions Asked
1. Remembering (Knowledge)	Student recalls or recognizes information, ideas, and principles in the approximate form in which they were learned.	memory, knowledge, repetition, description	1. What do the charts show? 2. Define.... 3. List the three.... 4. Who invented...?		
2. Understanding (Comprehension)	Student translates, comprehends, explains data and principles in her of his own words.	explanation, comparison, illustration	1. Explain the.... 2. What can you conclude...? 3. State in your own words...		
3. Solving (Application)	Student selects, transfers, and uses data and principles to complete a problem task with a minimum of directions.	solution, application, convergence	1. If you know A & B, how could you determine C? 2. What would happen if...?		
4. Analyzing (Analysis)	Student distinguishes, classifies, and relates the assumptions, hypotheses, evidence, conclusions, and structures of a statement of a question with an awareness of the thought processes being used.	logic, induction & deduction, formal reasoning	1. What was the purpose of? 2. Does that follow? 3. Which are observations, and which are inferences?		
5. Creating (Synthesis)	Student originates, integrates, and combines ideas into a product/plan that is new.	divergence, productive thinking	1. Make up.... 2. What would you do if?		
6. Judging (Evaluation)	Student appraises, assesses, or criticizes on the basis of specific standards and criteria.	judgment selection	1. For what reason would you favor...?		
			TOTALS		100%

Figure 4-1. Classroom Question Classification Method for Science Teaching

In teaching science you will realize that high-level questions demand more science activities. In addition, you will find yourself reducing the number of "right answer" questions, with a concomitant increase in the number of open-response questions. And this is just what you want to do!

Applying Three Strategies

The preceding discussion should have given you a better appreciation of the role that questioning plays in stimulating student achievement in science, as well as of the crucial effect that your questions have in encouraging higher-level cognitive processes in your classroom. As an operating procedure it can be generalized that the type of questions you ask will be viewed by the students as indicating the types of learnings that are important.

For your convenience, all science questions--whether asked by teacher or student--might be classified into three categories or patterns: (1) convergent, (2) divergent, and (3) evaluative.

Convergent Questions

As the term denotes, the convergent questioning pattern focuses on a rather narrow learning objective and utilizes questions that elicit student responses that converge or focus on some central theme. Convergent questions for the most part elicit rather short responses from students--e.g., "Yes" or "No" or very short statements--which tend to be at the knowledge or comprehension level. The use of the convergent technique per se is not to be construed as being "bad." There are many situations in which you might desire the students to demonstrate a knowledge of specifics, and thus lower-level questioning strategies would be most appropriate.

For example, if you use an inductive teaching style (proceeding from a set of specific data and aiming for student conclusions) then you utilize a large proportion of convergent questions. Or you may wish to use short-response questions as warm-up exercises by which to open, close, or break the monotony of the traditional classroom, perhaps using a "rapid-fire" approach. This technique would be most appropriate where you are building vocabulary skills; keep in mind that much of science is initially learning a kind of foreign language.

The use of a rapid-fire convergent technique also allows for participation by a very large number of students as you focus on specific learning objectives, skills, terminologies, or solutions to easily solved activities having a specific "answer."

Below is a list of convergent questions. Note that these questions all meet the criterion of focusing the student responses on a narrow spectrum of possible options, and that responding students will rely on simple recall more than analysis.

1. How could heating a tin can with a little water in it and then capping it possibly cause the can to collapse?

2. Under what condition does water expand?

3. What effect does acid have on blue litmus paper?

4. Where do you find the tallest dandelion plants?

5. What are the Van Allen Belts?

Patterns for Divergent Thinking

Divergently oriented questions seek responses that lead to a spectrum of responses. Divergent questions also elicit longer student responses.

When the results of experiments or science activities are being discussed and you want to elicit a wide array of student responses, divergent types of questions are appropriate because multiple responses almost always occur. You can capitalize on this by asking a question that can be answered with multiple responses, calling on three or four students in turn, and then assuming a passive role in the discussion; this, as you know, is a rather sophisticated strategy. And because divergent questions generate a multiplicity of responses, you must be prepared to accept all student responses, to allow or encourage novel solutions and creative responses.

One technique that will aid you initially in framing divergent questions is to write the questions on paper prior to asking them. In this manner you can examine them to ensure that they are clearly stated and convey the precise meaning you intend. The first time you use divergent questions, you may find the class experience rather difficult or even disappointing. Because many teachers still devote the majority of time to the oral recitation of very low-level learnings, students may not be conditioned toward providing responses that are longer and/or that result from higher-level thought processes. It takes a good deal of reshaping of student behavior patterns to elicit proper student responses through divergent questioning techniques. But alert the students that the questions will be varied and have patience. By using divergent questioning you will soon discover that your students are dealing in the higher-level thinking categories of the cognitive taxonomy--i.e., application, analysis, and synthesis.

Science by its very epistemology--the verifiable experiment or activity--automatically creates diverse sources of information. Use those sources to create wider viewpoints in the class. Below are selected questions, adapted from the list previously presented as convergent questions, that may now be classified as divergent.

1. Why are structures collapsed when tornados pass by them, but do not hit them directly?

2. What would happen if water contracted rather than expanded when it froze?

3. How many ways could you test to determine if you have an acid or a base?

4. How does the environment affect the early development of young dandelion seedlings?

5. Why would one want to know about the Van Allen Belts?

6. If we exhaust the nation's petroleum resources within 10 or 20 years, what will be the impact on our standard of living?

7. List as many alternative fuel sources as you can, other than gasoline or oil.

The Evaluative Questioning Pattern

The third basic pattern of questioning is one that utilizes divergent questions, but with one added component--evaluation. The basic difference between a divergent question and an evaluative question is that the latter has built within it an evaluative or judgmental set of criteria. When you ask why something is "good" or "bad," you are raising an evaluation question. However, because it is possible that an evaluative question might elicit nothing more than a poor collection of uninformed student opinions, you must emphasize the criteria by which a student gives a judgment. These criteria should concern the worthwhileness or the inappropriateness of an object or an idea.

You can systematically help students to develop a logical framework by which to establish evaluative criteria. For example, if you ask a question and the student replies with "Because," then you must recognize that the student is lacking in logical perception, may be dogmatic or arbitrary, or just does not understand how to go about framing a logical and consistent set of evaluative criteria. Once again, we caution you not to use sarcasm or any other put-down technique; the typical teacher comment that "You're not being logical" gives the student no basis for improvement whatsoever. Take a positive approach and reinforce the student by providing examples that yield a logical development of evaluative criteria. Provide a specific set of criteria or specific items so that the student develops his or her own specific set of criteria. In this manner, a student will understand why value judgments and opinions are being held.

Observations tend to verify that as evaluative questions are presented and student responses elicited, the teacher and the students tend to classify the evaluative responses along some type of continuum ranging from "bad" or illogical responses to "good" or logically developed responses. How do you classify evaluative responses? By logical development, internal consistency, validity, and perhaps responsibility are some options. In short, it is suggested that you accept all student responses and that you discuss apparent logical inconsistencies that develop after the student has had an opportunity for classroom discourse.

Following are examples of evaluative questions. Remember, most, if not all, evaluative questions will be divergent; the one criterion that separates divergent questions from evaluative ones is that the latter rely on the establishment of judgmental criteria or the judging of the value of some idea based on other pre-established values, criteria, or conventions. Note that some examples previously designated as divergent questions have been converted below into evaluative questions.

1. Why is Newton's Third Law of Motion--"For every action there is an equal and opposite reaction"--so important in our lives?

2. Why is the world a better or worse place in which to live because of computers?

3. React to the following newspaper headline: "Inventor Claims Perpetual Motion Machine."

4. How has the federal system of interstate highways harmed or helped our environment?

5. Defend or reject the strip mining of coal in eastern Montana.

6. What criteria would be important in accepting plate tectonics as a testable theory.

Did you realize that in discussing divergent and evaluative questions, we have been using the term responses, not answers? Answers carry the connotation of being complete or the single absolute final word. To be sure, convergent questioning patterns may elicit student answers. However, you must recognize that when divergent and evaluative questions are framed, the students will be providing responses--the degree of finality is not there.

Technical and Humane Considerations

Framing the Questions

The use of classroom questions in a science period, a tutorial period, or an inquiry session is always predicated on the assumption that meaningful or purposeful learning activity is taking place. To ensure that this occurs, you must ask questions in a positively reinforcing manner. That is, questions should be used so that the student enjoys learning and reciting about science and will receive polite, sensitive and positive reactions to his or her responses.

The basic rule for framing a question is: Ask the question; pause; call on a student. This rule is grounded in the psychological principle that when a question is asked, and then followed by a short pause, all students will "attend" to the communication. Being communicated is the nonverbal message that you might ask any student in the class to respond. Thus, the attention level of the class remains high. If you reverse this pattern by requesting a particular student to respond prior to actually asking the question, then all those students who are not involved have an opportunity "not to attend" to the communication between you and the student. This basic type of question framing can be used even when employing the multiple response technique wherein you request several students to respond.

When you develop the habit of pausing after asking a question, you will learn not to "dread" the wait time. Mary Budd Rowe (1973-1974) discovered that teachers are most impatient with students when asking science-related questions. She measured the "wait time" of many metropolitan school teachers and found that wait time between asking a question and either answering the question before the student or calling on another student had to be measured in fractions of seconds! Is it any wonder that some students dreaded to be called upon. They knew it would elicit impatient and negative behaviors from the teacher. We want you to know that classroom silence is not bad when asking questions and waiting for the responses.

Probing Techniques

Once activities have been concluded, a question has been asked, and a student has been identified to respond, there is always the possibility that the student will not answer the question completely. This is a common occurrence in science classes. When this does happen, you need to move into probing or prompting strategies that attempt to clarify the question. Clarifying tends to help the student to understand it better. By seeking clarification a student can amplify the response, or elicit additional responses. In this manner, you can verify whether or not the student comprehends the material or not.

If a student has neither clarified the question nor adequately amplified the response, then use a probing technique. To do this in a positive manner, acknowledge the attempted response but then encourage the student to clarify or amplify it.

Prompting

During a science discussion you must prompt students so that an incomplete response can be transformed into a more complete or logical response. Basically you will use the same technique as discussed above regarding probing--i.e., you will always aid the student with a positive reinforcement so that the student is encouraged to complete any incomplete response or revise an incorrect one. In most cases the student will respond to a question with a partially correct response. Or stating it negatively, a student will often respond with a partially incorrect response in addition to a partially correct one. Immediately upon hearing a response that fits this category, you begin to prompt the student so that the response can be completed, made more logical, re-examined, or stated more adequately or more appropriately.

Handling Incorrect Responses

No matter how skillful you are in motivating students, providing adequate and relevant instructional materials, and asking meaningful questions, there will be one continual problem that detracts from the intellectual and interpersonal activities of a science lesson--incorrect student responses.

As was discussed previously, you can use probing and prompting techniques when a student response is partially correct or incompletely stated. Basically, prompting and probing are rather easy techniques because you can reinforce the positive aspect of the student's response, while ignoring the negative or incomplete component. However, when a student gives a totally incorrect response, a more complex situation arises. First, you have little to reinforce positively, and such teacher comments as "No" or "That is incorrect" act as negative reinforcers which, depending on the personality of the student who responds, might reduce her or his desire to participate in science discussions or recitations. Second, if you respond very adversely to an incorrect student response, there is a high probability that the "ripple effect" will appear. Jacob S. Kounin (1970), who has so described this effect, demonstrates that students who are not themselves the target of the teacher's aversive strategy are, in fact, affected by what the teacher does to other class members.

What, then, can you do? Since the entire approach to this method is to stress the positive, the first decision you might make is whether any portion of the student's verbal response can be classified as valid, appropriate, or correct. Following this "split-second" decision-making, you must then provide positive reinforcement or praise for that particular portion. When an incorrect student response provides no opportunity for positive reinforcement, you might attempt to move to a neutral probing or prompting technique. For example, you might state, "Your response is in the magnitude of the answer," or , "Could you tell us how you arrived at your answer?" Note that none of these responses is totally negative, but can be considered as neutral, as they are not positive either.

Concept Review Questions

As you begin to develop confidence in using various questioning techniques, it becomes necessary for you to review in a most efficient manner those previously learned science concepts and to relate or correlate them to knowledge that will be generated at a later date. In most cases, teachers tend to schedule a review prior to a summative evaluation. "Review

Thursday" tends to be an ineffective use of student time in that the vast majority do not need the review, and for those students who do, such an oral exercise is usually fruitless in expanding their intellectual understanding of whatever it is that the teacher desires.

How can you review previous concepts while conducting questioning strategies? One successful method is to repeat concepts discussed previously but in the context of newly presented material. For example, if you are progressing through a unit on electrical currents, and the topic of batteries has already been covered, and a related topic--e.g., chemical reactions that produce energy--is being studied, you begin to ask questions relating to batteries and their chemical reactions. It's that simple.

The concept review technique requires that you be always on the alert for a teachable moment that will allow a meaningful review to be established, a previous concept to be reinforced, or a synthesis of knowledge to take place, thereby creating one more motivational factor for the class.

Encouraging Nonvolunteers

With most science activities, you will have no problem encouraging students to respond to questions or to present their findings to the class. But what are some helpful strategies in motivating nonvolunteers to respond verbally during a questioning session?

The first technique is to *maintain a highly positive approach toward the student*. Once the nonvolunteer has responded appropriately, there should be positive feedback to encourage the student to continue such behavior. Another technique is to ask rather easy evaluative questions since most students respond to questions that concern judgments, standards, or opinions.

Another method that can be used to increase nonvolunteer participation is to make a game out of questioning from time to time. Place each student's name on a card so that you can draw the cards at random, thus creating a condition where every student could be called on to recite.

There is nothing wrong with giving known nonresponding students a card with a question on it the day before the intended oral recitation period. Very quietly hand these students a card and tell them they might check over the assignment so that they can summarize their responses for the next class period. At least this method begins to build a trusting relationship between you and the students.

We do not condone calling on nonvolunteers for aversive or punishment tactics. Schooling ought to be positive with affective consequences of "approach tendencies" being emulated. As a general rule the most influential means by which you can encourage a nonvolunteer to participate is to be sincere and genuine in treating each student as a human being. Nonvolunteers have learned, and probably painfully, that it doesn't pay to say anything in the class because the teacher will "put you down" anyhow.

Developing Student Skills in Framing Questions

The previous techniques have been oriented toward the teacher, but there is another source of questions that is often overlooked--the students themselves. Classes can be organized to encourage student communication, giving each one a chance to express opinions and ideas; but evidence shows that teachers do most of the talking.

Studies have shown that (1) students can be encouraged to ask productive or higher-level questions, (2) the more questions a student asks per period, the greater the probability that the questions will be at higher levels, (3) praise will encourage and stimulate more productive thinking processes among students from lower socioeconomic backgrounds, and (4) students become more involved in the classes in which they are encouraged to ask questions.

To teach students how to frame their own good questions, refer to the game that was first made famous many years ago on radio, "Twenty Questions." The game of "Twenty Questions," in which participants ask questions to identify something, can be applied in the classroom. You can present a problem or identify some concept that needs to be discovered and then allow the discovery to take place only through student questioning. Initially you conduct the session. But as students become more proficient at questioning skills, then they should conduct the entire session with you merely analyzing the various interpersonal reactions.

J. Richard Suchman (1966) prepared an Inquiry Development Program published by Science Research Associates where the emphasis is on developing student questioning skills. Using his approach, you present a problem to the students and then play a passive role in the learning, responding only with a "Yes" or a "No" to any student's question. What this means is that the students must learn how to ask questions on which they can build a pyramid of knowledge, ultimately leading to a convergent response or answer, rather than simply a series of unsystematically asked questions. When this technique is utilized with students who have had almost no opportunity in the classroom to ask questions, the initial results can be rather "sad." However, you should review each lesson and give precise and detailed directions on how the questioning can be improved. As one alternative, if it would not be too slow, you might initially write each student's question on a chalkboard or on an overhead projector transparency so that each student would have visually presented those questions that are asked by her or his peers. In this way information and skills can be built up gradually in a somewhat systematic manner.

Of course, when developing student skills in framing questions, it becomes imperative that the students understand the logic that each question must encompass a large category of specifics. In short, you provide practical application to deductive logic skills.

Another alternative to use in developing students' skills in framing questions is to have students prepare recitation questions based on the science data being studied or generated from student conducted activities. In this manner you can assign a few students each day to prepare a series of questions for their peers. To be sure, most students will be oriented only toward facts since that is what is most often reinforced in their learning. But if you are skillful in continually reinforcing those questions that are aimed at higher-level thinking skills and in ultimately helping each student to prepare appropriate higher-level thinking questions, you will gradually observe improved questioning skills.

As a teacher, you will observe that as you begin to encourage the class members to ask questions of each other, there is a subtle shift of responsibility to the class. Teachers usually admonish their charges to "accept more responsibility." We submit that it is in the learning situations where greater responsibility may be acquired. The latter statement implies that responsibility is a "learned behavior" just like so many other behaviors. As a teacher you owe it to your students to help them become more articulate and thoughtful individuals. What a splendid opportunity exists by a slight shift in classroom questioning techniques. As was stated previously, this technique must be carefully explained to the students and then practiced for a few class periods. You and the class can generate a set of criteria that provides information or rules by which the various student-made questions are framed. Then, perhaps once a week or more often, the students can conduct the questioning sessions. Further, this method acts as a prerequisite experience to student-led discussions.

Teachers with whom we have worked have all been pleased with the results of such techniques. And, more importantly, these same teachers were amazed at how they underestimated the potential that existed in their classes. We are not implying that these techniques are simple to implement. It takes much practice and planning. But the attendant rewards make both teaching and learning more worthwhile.

Teacher Idiosyncrasies: A Caution

One can speculate that all teacher behaviors that may be associated with questioning are positive and encouraging. After all, the teacher is assumed to need only a few tricks and a smile to achieve instant success. Unfortunately, there are teacher behaviors that, when used inappropriately, may interfere with a smooth verbal interaction pattern in the classroom. Briefly, these idiosyncrasies are: (1) repeating the question; (2) repeating all student responses; (3) answering the question; (4) interrupting a student's long response; (5) ignoring the responding student; and (6) calling on the same few students. Each of these behaviors will be analyzed.

Repeating the Question

A common error often made by teachers is the regular repetition of each question. This habit conditions the students to catch the "replay" of the question instead of "attending" to it originally. This bad habit causes a loss of valuable time, is redundant, and does not help the teacher to maintain efficient classroom management. To be sure, there are appropriate times to repeat questions: in a very large room with poor acoustics; when the question is multifaceted; when the question is not adequately framed; or when the teacher is dictating a question to the class. We do caution that beginning teachers often have difficulty in framing verbal questions that are understood explicitly by the students. In such cases, the teacher should rephrase the question for added clarity. Repeating a question may be appropriate when one uses divergent questions. However, in most cases, repeating a question should be avoided.

Read the following two sets of repeated questions aloud to friends or colleagues and obtain their reactions.

Teacher: What is the main set of criteria by which to frame questions? In other words, what is the main set of criteria by which to frame questions?

Teacher: What is the atomic weight of Sodium? What is Sodium's atomic weight? How much does an atom of Sodium weigh?

How did they respond to the repetitious questions? Listen to teachers or professors in oral discourses to determine whether or not they repeat their questions. If you have not observed this idiosyncratic pattern, then obtain a tape recorder, tape a simulated version of this pattern, and play it back to a small group of peers. We will wager that after listening to a few of these simulated episodes, your audience will be highly amused. This may make a creative term project for your methods class.

Repeating all Student Responses

An equally distracting and time-wasting technique is to repeat all or nearly all of the student verbal responses. Not only is this a waste of time, but it causes a class to ignore its peers as sources of information and subtly conditions the class to wait until the word comes from the "fount of all wisdom." In short, students either do not attend to the initial student response or wait for the "instant replay" from the teacher. If the teacher is the least bit sensitive to the building of positive student self-images, then he or she will not want to be the center of verbal interaction and will attempt to keep the focus on the responding student. After all, if it is important to call on a student and require a response, then it ought to be equally important that student statements be given the same priority as teacher-made statements.

This general rule does not hold for large-group sessions. Most large-group rooms or halls have poor seating arrangements, so that the teacher must almost always repeat student responses so that all can hear. The same is true for students with very soft voices. But in the vast majority of cases, there is no need to repeat student responses. Finally, if the teacher wishes to condition the students to pre-discussion behaviors, then comprehension of this technique is essential. To put it positively, by allowing students to take cues from each other, the desired attitude will be established, so that introduction of true discussions will be a logical sequence.

Answering the Question

Have you ever observed or participated in a class in which the teacher carefully frames a question, pauses, calls on a student, then quite insensitively answers the question? First of all, this idiosyncrasy is a morale defeater. How can students be encouraged to think when they know that the teacher will hardly allow them to voice their opinions? This behavior also tends to discourage volunteers and causes students to be negatively reinforced. If a question is so complex that no student can answer it, then the teacher should rephrase it, begin prompting, or assign it as a research project. As we mentioned earlier, Marry Budd Rowe (1973 and 1974) found that teachers usually do not wait for student responses or, worse yet, had "wait times" that measured in fractions of seconds! These findings are a heavy indictment, to say the least.

Interrupting a Student's Long Response

One very distracting, inappropriate, and rude teacher idiosyncrasy is to ask a question and then interrupt the student by completing the response or by adding personal teacher comments without attempting to elicit other student responses. An example follows:

Teacher: What impact has the Hydrogen Bomb had on our young persons? (Pause.) Arnie?

Arnie: Well, I sure don't trust . . .

Teacher: Right, you kids really don't have the confidence in our government. Why, I can remember when I was in high school . . .

Teachers who suffer from excessive talkativeness frustrate students and, worse, neglect to allow them to develop logical response systems. This interruptive technique discourages most students from even participating in the recitation period.

Ignoring the Responding Student

When the teacher calls on a student, the teacher should show a courtesy to that student by attending to (that is, listening to, or at least appearing to listen to) him or her. After all, the teacher expects to instill attending habits in the students. This habit should be reciprocated during verbal interactions. After all, how would you feel if you were responding and observed that the teacher was gazing out the window or counting some loose coins? We suggest that teachers often fail to reinforce appropriate student behaviors in the class by simply being insensitive to the feelings of others.

Selecting the Same Student Respondents

One frequently heard student complaint is that "my teacher never calls on me" or that "the teacher has a few pets that are always being called on." These statements typify the frustrations of students who recognize partiality when they see it. The biased teacher who calls on only a few (usually highly verbal and successful) students is providing a negative reinforcer to the majority of the class members, is making them disinterested in the subject, and causes serious erosion of the group morale.

Lest you be doubtful, let us remind you of Ray C. Rist's classic study, which was conducted in a Chicago elementary school. Rist (1970) observed that a teacher in a primary grade was exhibiting great bias in the manner in which students were selected for class recitations. Fewer and fewer individuals were being called on by the teacher until only a select few were identified. To make matters worse, the teacher began to move the responding pupils up to the front seats and the others, the nonrespondents, to the rear of the room. Needless to say, there were tremendous disparities between the educational achievements of the "front rowers" and those of all the other students. The teacher and pupils were all of the same ethnic group, so racism can be eliminated as the basis for bias. This may be an extreme case, but in general, such a situation exists to varying degrees in most classrooms.

A quick way to determine whether or not you show bias is to ask a different student each day to list the number of times that you call on each student. A quick tally at the end of the week will provide the data.

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It is tempting to call on students who often volunteer and who will give you the "right" answer, so that you will appear to be an effective teacher. But if you wish to encourage all your students to be winners, then you ought to accord them equal opportunity to do so. One motto is fairly accurate in this case: "Nothing breeds success like success." If students are hesitant about responding verbally, then you as the teacher (who assumedly is the most secure individual in the class) must gear the questions to suit the individual students, so that all students can enjoy the feeling of success and positive reinforcement.

The Status of Classroom Questioning

The purpose of this chapter was to indicate the functions of questions, their use as a teaching strategy, and the effects they have on learning. Our brief review of classroom questioning provides you with an indication of the apparent effects that questioning techniques have on learning processes. Now as a closing section, let's review a few selected research studies to provide evidence for these "tips."

Although questioning is an important instructional strategy, it appears that teachers may have mistakenly equated quantity of questions with quality. Amelia Melnik (1968) found that some teachers asked as many as 150 questions per class hour.

One of the earliest studies of questions in the classroom was done in 1912 by Romiett Stevens. She estimated that 80 percent of school time was used for question-and-answer recitation. Half a century later, a sample of high school teachers was found to have asked an average of 395 questions a day, with most of them being memory questions (Clegg, 1971).

Meredith D. Gall (1970) cited several studies in which large numbers of questions were used by elementary teachers--ranging from 64 to 180 questions in one class period to an average of 348 questions during the school day!

In Gall's (1970) excellent research paper, he cited eight studies that spanned a period from 1912 to 1967, which all showed that questioning practices changed little over this time.

Another apparent reason why teachers overuse fact questions is the lack of systematic teacher training in the use of questioning strategies. The Far West Laboratory for Educational Research and Development developed a self-contained, in-service mini-course to improve teachers' questioning skills. The Lab program used 16 mm films to explain the concepts and also includes modeling, self-feedback, and micro-teaching. The program was used with forty-eight elementary teachers in the Far West Lab field tests, and the results showed an increase in redirection questions (those requiring multiple student responses) from 26.7 percent to 40.9 percent; in thought-provoking questions, from 37.3 percent to 52.0 percent; and in probing (that is, prompting) questions, from 8.5 percent to 13.9 percent. There was also a concomitant decrease in the repetition of students' answers from 30.7 percent to 4.4 percent. The repetition of the teacher's own questions decreased from 13.7 percent to 4.7 percent, and the answering of the teacher's own questions by the teacher decreased from 4.6 percent to 0.7 percent (Borg et al., 1970).

We must note here that it is the micro-teaching component of the Far West Lab's mini-course that allows the teacher to practice and perfect questioning skills. Studies by Donald C. Orlich et al., (1972, 1973) revealed that when teachers were trained in questioning, the frequency of higher-level questions used in the classroom increased significantly.

Questions and Cognitive Effects

There are a number of research and quasi-research studies reported on questioning. However. the most significant study to emerge in the last decade is a review of wait time by Kenneth Tobin (1987). Recall, that wait time is that technique where a teacher asks a question, pauses for at least three seconds, then calls on a student. In the literature this is called "Wait Time I". (Wait Time II" is the wait time after a student responds before the teacher talks.)

Tobin reviewed all the published studies over a 20 year period regarding wait time. After analyzing these studies and discussing them he listed changes that took place in teacher questioning behaviors when they used the techniques (as we previously described).

In general, the teachers using wait time technique:

1. Had less teacher talk.
2. Repeated themselves less.
3. Asked fewer questions per period.
4. Asked more questions that had multiple responses.
5. Asked fewer lower level questions.
6. Did more probing.

7. Repeated students responses less.
8. Asked more application questions.
9. Had some increased anxiety as they implemented the technique.

Reflect on the above findings. They tend to support the total method presented in this chapter.

Now, what impact did the techniques have on student behavior? In general students associated the use of wait time:

1. Made longer responses.
2. Had more student discourse.
3. Had fewer nonrespondents.
4. Increased complexity of answers.
5. Had more student initiated questions.
6. Had more student to student interactions.
7. Had less confusion.
8. Had more confidence.
9. Had fewer peer interruptions.
10. Had higher achievement.

Again, these findings illustrate the efficacy of the total questioning method endorsed herein. The results reported by Tobin almost demand that any responsible teacher must learn the total method of questioning.

In an earlier study, Meredith D. Gall and associates (1978) reported that their experiments on questioning, recitation, and learning seemed to support the idea that recitation teaching was more effective in promoting student learning than a nonrecitation instructional experience lasting the same period of time. They also noted that students learned equally well when the teacher gave the answer to a question a student did not know or when information was provided by their peers. This study provides evidence that fact questions were not harmful to the learning of higher cognitive skills.

These results, of course, must be viewed with reservation as the experimenters had groups of only six students per recitation. In the groups, the teachers used a scripted set of questions so that there was little deviation from the questioning plan.

Two conclusions drawn from this study are: (1) well-designed questions and strategies may be more important than the level of questions; and (2) when you work with very small groups, there is a tendency for greater efficiency in learning.

The evidence is becoming more conclusive, there does appear to be a direct relationship between the level of questions asked by the teacher and the level of student responses. Furthermore, it appears that if a teacher decides to raise his or her expectations for the class and systematically raises the level of his or her questioning, then the students accordingly raise the level of their responses. Of course, this implies a carefully planned questioning sequence that would probably span several weeks of instruction. The major caution is not to jump haphazardly into high-level questions without making the necessary teacher-student attitude adjustments. This means that teachers must plan for the utilization of appropriate questions just as he or she plans for the next week's reading assignments. (There conclusions are not entirely valid in every case, as is shown by J. T. Dillon, 1978.)

There are some implications of these studies for teacher decision-making. First, if teachers want their students to develop higher levels of thinking, to evaluate information, to achieve more, and to be more interested, then teachers must learn to ask higher-level questions. Second, teachers must encourage their students to ask more questions--and more thought-provoking ones--if they desire greater student involvement in the process of learning. Finally, we should add that the type of questions to be used is the teacher's decision.

Another important consideration for teachers who desire to stimulate critical thinking is the use of textbooks. Teachers should be aware of the advantages and disadvantages of their textbook materials. To attain the objective desired, the teacher may have to supplement the materials provided. For example, John P. Rickards (1976) wrote that he inserts written textbook questions into the various passages being studied, so that the students will not have to wait until after the chapter has been read to complete the questions.

It should be noted that you can use questions to: (1) diagnose student progress; (2) determine entry-level competence; (3) prescribe additional study; and (4) enrich an area.

We refer you again to Meridith D. Gall's excellent research summary (1970) for an illustration of several systems that have been developed to classify the types of questions that are utilized by teachers. You will observe distinctions between the various systems, in addition to the commonalities. Of the question classification systems, Bloom's is apparently the most widely used. Although it is not simple to use, it does have the advantage of being descriptive enough to allow for in-depth analyses.

Summary

The previous review of studies that relate to questioning is provided so that you may better appreciate the impact that this technique has on the learning environment of the classroom as well as the kinds of studies that have been conducted. You may wish to itemize several points that can affect your own questioning skills. Below is a brief list of findings that summarize the results of over a half century of research.

1. Questioning tends to be a universal teaching strategy.

2. Being systematic in the use and development of questioning tends to improve student learning.

3. By classifying questions according to a particular system, the teacher may determine the cognitive or affective level at which the class is working and make adjustments as professionally indicated.

4. Through systematic questioning, the teacher may determine the entry levels of students for specific content areas.

5. A wide variety of questioning options is open to teachers.

6. No one questioning strategy is applicable to all teaching situations.

In addition to the generalizations that are substantiated by research, we also have assumed that higher-level questions demand greater intellectual activity. The research available to date seems to confirm that assumption. Rather than emphasizing a "right" answer, teachers should use questions to stimulate higher cognitive achievements and to make information more meaningful. In the long run, the _quality_ of the questions being asked should be most important. Walter Borg, one of the creators of the Far West Lab mini-course, concluded that questioning is one of the most essential functions of teaching (Borg et al., 1970). If this generally accepted assertion is valid, then teachers must achieve a high degree of sensitivity and awareness to use questions in the most efficacious and appropriate manner.

If you have perceived that we are attempting to make a "game" of science teaching, then you are absolutely correct! Science ought to be a time in which everyone has fun learning or at least will have *approach tendencies* while learning. If science can be meaningful and relevant, then students will enjoy *working* at it. Students have approach tendencies for those areas in which they are successful; if science is distasteful, then it is because, for the most part, students have been unsuccessful in science. Such an attitude can be easily rectified by making science, or for that matter all subjects, success oriented.

All of the above questioning strategies must be considered among your tools of the trade. But learning would soon become a very trite and boring exercise if it were centered only about questioning. While questions comprise an important set of teaching tools, they are just that--tools. Each technique must be used appropriately and must be congruent with the objective that you have for any specified student, group of students, or class.

Finally, you might realize at this point that the techniques you need to apply to improve the teaching of science are some of the same that can be used to improve all subjects.

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CHAPTER 5

USING SCIENCE-RELATED DISCUSSIONS

The most successful elementary school teachers tend to mix individual and small-group work. Both of these topics have been previously introduced. Thus, those promised elaborations emphasizing process objectives rather than performance or behavioral objectives now begin. The latter type of objectives specifies exact learner behaviors in terms that allegedly make learning observable. Nearly every teacher in America knows how to identify, write, and specify learning in performance terms.

However, there is yet another type of objective that may be of equal, if not greater, importance--the process objective. A process objective requires the learner to participate in some technique, interaction, or strategy. Process building is much more subtle than specifying performance objectives and requires that you carefully plan experiences for the learners. As was mentioned previously, the schools should develop responsibility, a process which takes years to accomplish and which some individuals never master. Development of a process such as responsibility requires that the students have something about which to be responsible. Likewise, practice, planning, and cumulative experiences are all necessary to develop successful processes in small-group and discussion techniques.

It may be confusing to use process with two definitions: (1) the 13 scientific processes, and (2) the process objectives that relate to learner interaction with techniques or strategies. So, to avoid any problem with semantics, we will always refer to the first class of processes as scientific processes and the second classification as interaction processes.

On analysis, you will discover that the scientific processes tend to belong to the cognitive domain of skills, while interactive processes tend to fit the realm of the affective domain--the attitudinal dimensions of life and learning. Let us examine how you can determine the status of your classroom group and what organizational and individual developments are necessary to use the interaction processes most effectively.

Organizing for Process Skills

Establishing Goals

The first requirement of conducting a successful small-group science learning activity through either discussion or small-group learning is the development of a set of *long-range* priorities. While performance objectives are written for the immediate interaction, process objectives are written for the development of skills, attitudes, and knowledge that require long periods of time to develop. Long-range objectives are important because, as the planner, you must identify the skills that the learners must demonstrate before they can approach or achieve mastery of any stated objectives.

As an aid to your long-range planning there are several skills that both you and the learners must be able to demonstrate. These might initially be called pre-discussion skills. Below is a listing of both the order and the types of skills that are prerequisite to conducting successful small-group discussions in science.

1. The teacher knows how to select and ask questions in a systematic manner.

2. Students learn to respond to divergent questions.

3. Students learn to respond to evaluative questions.

4. The class is subdivided into small groups to discuss topics that require divergent and convergent responses.

5. Students can complete committee tasks.

6. Students learn to ask questions of each other and of the teacher.

7. The teacher identifies the needed interaction processes for specific individuals and for the class as a group.

8. Small-group units are formed in the class.

9. The teacher prepares student leaders, recorders, and observers.

10. The class is subdivided for teacher-led small-group discussions.

11. All class members comprehend the concept of formative evaluation.

12. The teacher and the students plan for appropriate discussions.

13. Students learn roles for various discussion techniques.

14. The class is subdivided for student-led discussions.

15. The entire class critiques and evaluates small-group efforts.

16. The processes associated with small-group discussions are incorporated into the ongoing activities of the class.

On first reading, you might be overwhelmed. Please don't be. The above 16 major tasks are easily incorporated into science instruction, but they are also easily implemented during social studies or language arts lessons. The list is provided to help you evaluate your own classroom and what needs to be done to improve student skills through meaningful experiences.

You already have studied, and perhaps mastered, the art of questioning which was detailed previously. More than likely you are already using some elements of individualized learning such as learning centers in your classroom. Most teachers utilize some small-group activities, often through committees. All that we are proposing is that you extend these tested teaching strategies to the field of science in a systematic manner. Let us develop the entire technique.

Using Small Groups

Small-group learning units are most appropriate for elementary school science to increase teacher-student and student-student verbal communication and interaction. By using small groups, you add flexibility to your instruction. Teachers who use small groups report that this technique helps students reflect a more responsible and independent mode of learning. It is important to note, however, that you must identify and sequence a systematic and planned set of procedures, experiences, and objectives. During the actual lesson, students become active participants in the class activities, but in groups of two, four, or six.

How do you start? To initiate small groups or discussion groups requires that you simply restructure the manner by which individualized work takes place. Because most modern elementary school science programs have an activity orientation, you can begin by selecting an activity and then organizing a division of efforts among the class members. Each group member then has some specific task to accomplish--e.g., pick up and return the science materials, make a table to record data, set up the apparatus, conduct one aspect of the activity.

When learning activities result in more divergent types of experiences, it is more appropriate to have groups of four accomplish some assigned science objective. Collecting data or preparing histograms or tables can be difficult tasks for some students. By using a small-group approach you can help selected students become more competent in cognitive, affective, or psychomotor skills.

Teachers have collectively identified at least 12 goals or purposes for using small-group or discussion techniques in teaching elementary school science:

1. Interest can be aroused at the beginning of a new science topic or the closing of one.

2. Small groups can identify problems or other issues to be studied, or they can suggest alternatives for pursuing a topic under consideration.

3. A small group can explore new ideas or ways to solve problems, covering either the entire problem-solving cycle or just one phase.

4. Discussions provide an opportunity to evaluate data, inferences, sources of information, and methods by which the data are generated.

5. Small groups allow students to demonstrate individual strengths.

6. Students often learn faster and better from each other.

7. Students are provided an opportunity to use the vocabulary of science in an appropriate context.

8. Cooperative work skills can be developed through practice in small-group discussions.

9. Skills in leadership, organization, interaction, research, and initiative can be learned and improved through discussion techniques.

10. Ideas become more meaningful and personal if a student experiences them. Flexibility in understanding other viewpoints may be improved.

11. Discussion can provide the students (and you) with opportunities for learning to accept and value other ethnic and/or cultural backgrounds.

12. In a small group or discussion situation everyone can participate and feel good about that contribution.

After reflecting on these 12 possible outcomes from the use of small groups or discussions, ask yourself this question: "How many topics in my current science program lend themselves to a discussion, based on those 12 potentials?" If you are uncertain, examine your science program or textbook. Undoubtedly you will identify several topics that can be easily incorporated into a series of small-group discussions. Remember: A discussion is used to accomplish an objective--either process or content.

Now ask yourself: "What kinds of sharing experiences do I want for my students?" You probably responded to this question by focusing on sharing different cultural experiences. You may have thought about the need for students to display and share their unique talents. No doubt you thought of the disadvantaged and handicapped students, and of their need to be in a supportive and sharing environment.

The two preceding questions are important because you may be teaching in mainstreamed classes. Also you may teach gifted and talented groups. And, of course, you will be faced with the challenge of providing a nonsexist, multiculturally oriented education for all your students. By using small-group discussions you will help your students to meet the challenge of growing up in what may be culturally, ethnically, physically, and emotionally different environs--the public school.

Developing Small Groups

Group size is an important variable because it influences learner participation levels. To state absolute minimum or maximum numbers to ensure successful interaction is difficult. An optimal size generally appears to range between four and eight.

When four or fewer students are involved in a science discussion group, there is a tendency to "pair-off" rather than interact. Conversely, the likelihood that all students will participate decreases when the group number approaches 12. With larger numbers--e.g. 15 or more--a few students tend to remain very interactive, a few somewhat interactive, and the great majority silent or passive. It seems appropriate to subdivide groups of 12 or more into groups of six to eight prior to the initiation of a small-group discussion. The topic, the group, and the leader's experience all affect this decision.

A discussion denotes an exchange of ideas with active learning and participation by all concerned. On the other hand, recitation tends to be a passive technique from the viewpoint of student activity. Discussion methods seem to be logical extensions of student interactions with materials or objects during science activities as student and student or student and teacher exchange thoughts. Discussions allow students to discover, develop, state, and react to personal viewpoints--not merely to repeat those ideas that you or a text has presented.

For purposes of clarification, a science discussion is described as including these elements:

1. A small number (6-12) of students meeting together.

2. Recognition of a common science topic or problem.

3. Initiation, exchange, and evaluation of information and ideas that relate to science.

4. Direction toward some goal or objective (often of the participants' choosing).

5. Verbal interaction--objectively and emotionally.

Why Use Discussions?

Discussions and small-group learning units are most appropriate if you desire to increase teacher-student and student-student verbal interaction in the classroom. Recall the 12 different goals for using small-group or discussion techniques that were described as being appropriate to aid students in becoming more responsible and independent learners. During the actual science lesson, students become active participants in the class activities and demonstrate both their scientific and their interaction process skills.

A well-accepted psychological principle is that students learn best when they are actively involved or participating. If you desire to promote a wide range of interest, opinions, and perspectives in the science class, then small-group discussions provide another way to accomplish that goal. If you desire to have different students doing different tasks or activities at the same time, all leading to meaningful goals, or if you desire to practice indirect control of the class, then discussion is an appropriate technique.

Small-group discussions provide an excellent method for dealing with controversial issues or open-ended questions. The need for a local, state, or national science policy, the problems of advocating a particular solution or point of view, and efforts to inform are all appropriate subjects for science-related discussions.

One criterion is critical in planning for the use of small-group discussion activities: Is the activity, question, or group task one for which there is abundant data? This criterion requires that you know approximately the range, amount, usefulness, and timeliness of available materials. If the students are limited in their research to collections of outdated, inaccurate materials, then they will not be able to challenge prejudices, develop open-minded and flexible approaches to new information, or learn how to reflect upon the acquisition of new knowledge.

It is your responsibility as a teacher to develop the habit of thinking in terms of the-students-and-I-working-together. A "we" attitude helps you in establishing clear goals that revolve around teacher-student relationships, student-student relationships, the learning purposes of the classroom, and a supportive emotional climate and learning atmosphere, so that each class member respects all other individuals and their respective ideas.

Every one of us has experienced, in either large or small classes, how the initial sessions are often marked by a lack of responsiveness and a general climate of anxiety. Group development and cohesiveness are attained only gradually. Effective small-group facilitators understand how to plan experiences that reinforce group goal setting, group effectiveness, group interaction, and group development.

Studies have shown that, when conducted under appropriate conditions, small-group methods are superior for selected purposes. There is evidence that changes in social adjustment and personality can be facilitated through small-group instructional methods. Further, it has been demonstrated that small-group activities help to increase the students' depth of understanding and grasp of course content. Two affective consequences have been demonstrated as being attributable to small-group techniques: (1) the enhancement of motivation and greater involvement by the students, and (2) the development of positive student attitudes toward course materials.

Finally, you will find that when you use small-group discussion techniques, your students will develop science problem-solving skills because they obtain greater practice in the application of concepts and because they realize that the content information has a practical use.

Two general skills--inquiry and cooperativeness-will tend to increase the effectiveness of the small-group participants. As groups develop cooperative members, the quality and quantity of learning become amazingly high. Conversely, if the group members compete with each other, there is a tendency for both the quantity and the quality of learning to decrease. Of course, to reach selected instructional goals, intergroup competition may actually be desirable (if not carried to an extreme). The overall success of small groups within your classroom depends on your selection of a blend of discussion modes, some of which require intragroup cooperation and a few that call for intergroup competition, which may be in the form of science-related games or simulations.

Techniques for the Classroom

Let us now address four well-tested small-group techniques that are most suited to science classes: (1) brainstorming, (2) Phillips 66, (3) tutorial, and (4) task groups. You might even mix some of these as you gain experience with them.

Brainstorming

A very simple technique that is useful when creativity is desired is brainstorming. Most science activities have some elements that require students to do some freewheeling-thinking. This is when you want to use a brainstorming group. Any number of students can become involved in a brainstorming activity. The shorter the discussion period is, the smaller the groups should be, so let time dictate the size within a 6- to 12-person limit per group.

The brainstorming session is started by the leader who briefly states the problem under consideration. The problem might be as simple as "How can we collect data about the problem?" "What problems need study in our school?", or as complex as "How can we set up an experiment to test seed germination?"

After the topic is stated and before interaction starts, it is crucial to select a method of recording the discussion. It could be taped, or one or more students who write quickly could serve as recorders.

Although all the students will be oriented to the rules, make sure that the student leader enforces these procedures. The following rules seem to be especially important:

1. All ideas, except for obvious jokes, should be acknowledged and recorded.

2. No criticism is to be made of any suggestion.

3. Members should be encouraged to build on each other's ideas. In the final analysis, no idea belongs to an individual, so encourage "piggybacking."

4. Solicit ideas, or opinions, from silent members. Then give them positive reinforcement.

5. Quality is less important than quantity, but this does not relieve the group members from trying to think creatively or intelligently.

Brainstorming is an initiating process and must be followed up with some other activity. *After* the discussion or brainstorming session, it is important that the ideas presented be classified by types and then evaluated for use by students in follow-up activities. One way to follow up would be to use the ideas generated in the brainstorming session as the basis for another type of discussion. Brainstorming can also lead to the prioritizing of the elements--e.g., when you desire a series of suggested science topics to be assessed in priority for future study.

The evaluation of a brainstorming session should not be lengthy, and it should be nonthreatening for the participants. Remember, you want everyone to contribute, regardless of their level of academic capability. You may want to make some private assessments about academic levels, levels of inhibition, or who is "turned off" by science; but all public evaluations must be highly positive in nature.

Phillips 66

The "Phillips 66" discussion group involves exactly six students, and was developed by J. Donald Phillips at Michigan State University. It is established quickly and does not call for pre-orientation. Students do not have to be highly skilled in group interaction for this type of discussion to work effectively. In fact, the Phillips 66 technique is most appropriate as an initial mixer activity.

The class is divided into groups of six (this can be done by you or on a volunteer basis). The groups then have one minute in which to select a secretary and a leader. At the end of one minute, you give a clear and concise statement of the problem or issue for discussion, worded so as to encourage specific single statement answers. The students then have exactly six minutes to come to an agreement or to arrive at the best solution for the problem.

When using the Phillips 66 group in the primary grades, you may decide to eliminate the role of secretary, but one of the students must summarize the group's solution. Listening and summarizing are important skills for group work, and the Phillips 66 method is a good training technique for future group leaders, recorders, and evaluators.

The Phillips 66 discussion group can be very useful as an initiating activity when teaching a major concept lesson or as a lead-in for a new science unit. You can probably think of many other appropriate times when it would be beneficial to focus the students' attention on a problem or concept and to create interest quickly in this problem or concept.

Your role is very simple. You decide on the topic, arrange the groups, start the discussion, and then systematically observe each group. After the discussion is over, you might want to discuss with the students ways that the leaders can keep the group focused on the task.

Tutorial

The tutorial discussion group is used most frequently to help students who have experienced difficulties in learning either basic skills, single scientific concepts, or who are absent from science classes. The group has only a few students (usually two to four) and focuses on a narrow range of materials. It is an excellent way to facilitate the handling of manipulatives or to demonstrate psychomotor activities.

The arrangements for a tutoring session should provide easy "eyeball to eyeball" contact to ease the flow of communication among all persons. The selected discussion leader (tutor) is clearly identified and, as such, plays a somewhat dominant role in the group process. This leader has three major functions to perform when in the tutorial mode: (1) questioning the group to pinpoint the exact problem that has blocked learning, (2) providing information or skills to facilitate learning, and (3) encouraging all to ask questions and seek answers among themselves.

Lest you have serious reservations about the tutorial technique, it has been demonstrated that students often learn better from each other than from the teacher! Many school districts currently use student tutors and are finding them to be invaluable resources for the classroom teacher. (Of course, a teacher aide makes an excellent tutor.) We caution, however, that prior to using student tutors, you must be satisfied that each one has mastered the necessary competencies--such as the skills of questioning, giving positive reinforcement, and analyzing work tasks. The student who leads the tutorial science discussion also needs to have developed some skills in the area of human relations. The leader must be patient, yet provide warm and friendly encouragement. The leader must also keep the group moving toward its goal, accept the inputs from those who learn slowly, and prod those group members who are slow to contribute.

Although probably most often used to alleviate student learning difficulties, the tutorial discussion group is an excellent method by which to encourage independent projects for advanced learners. Many gifted students will find it a challenge to try to explain their project to other students.

In 1984, Benjamin S. Bloom reported just how powerful the tutorial method is on student learning. His data showed that children would gain two standard deviations in learning when compared to the learning that takes place in the traditional classroom. To place that learning "leap" in perspective, keep in mind that a gain of two standard deviations would place those students in the top seven percent! Subsequent studies have shown that tutorials are the single best method by which to enhance student learning.

Tutoring can be used with one leader (tutor) and up to three other learners. Used with groups of two, three, or four, the technique actually becomes a discussion small group. Tutoring can be used in conjunction with science learning centers, reviews, formative evaluations, and analysis of data generated by students during an activity.

If you have but one choice of a discussion strategy to use, then make it tutoring.

Task Group

Another easy-to-use discussion type is the task group. As the name implies, students are involved in some type of work or activity in which significant contributions can be made by each group member. Prerequisite to using the task group is the specification of clearly defined tasks or assignments to all group members. The task group is very similar to a committee, having clearly defined goals, individual assignments, and roles. Further, it is beneficial for you to establish a work schedule and a system for internal monitoring of achievements, and initially to provide all of the learning resources that may be necessary to accomplish the identified tasks. At the scheduled conclusion of the task, each subgroup reports its findings to the entire class.

Task groups tend to be teacher dominated in that the teacher usually selects the tasks and assigns each class member to accomplish some specific role. This discussion type can be used very efficiently during the early part of a semester when you are attempting to provide students with specific scientific process competencies. Using this technique you can observe how selected students work with each other and how responsibly they tend to accomplish the task that has been assigned.

Introducing the Concept of Evaluation

Evaluation of discussions is designed to provide feedback to each individual who participates in the group activity. Since small-group discussions are interaction-process-oriented, that process should be continually evaluated so that each participant may improve. In the preparation of such evaluations, simplicity is the key concept. You ask what the goals or objectives of the activity are, identify appropriate criteria by which to judge each component, and then prepare a simple form for the evaluator.

Once the evaluator has judged the group activities, data from each individual should be compiled so that the group can receive aggregate or cumulative feedback. It is possible to tally all of the individual responses for each item and present the sums to the group. This technique allows each individual to compare the self-rating results to that of the group.

Evaluation forms, may be filed by you or by each student to determine the type and direction of growth for each participant. Such data enable you to help students who have not mastered specific discussion skills and to provide future direction for the group's use of discussion.

One form of evaluation is simply to record the number of times each student interacts verbally. This form could be prepared without any special printing. It would look like Figure 5-1. The evaluator tallies a mark each time any individual speaks. At the end of the discussion the leader, and perhaps even you, could examine the tabulation to determine if someone dominated the discussion or if someone did not contribute to it. The rationale for this type of evaluation is to promote interaction behaviors, not to blame anyone.

Names of Group Members	Number of Interactions
1. Laura Anne, Leader	~~1111~~ ~~1111~~ 11
2. Gus, Recorder	11
3. Jerry	1
4. Elaine	~~1111~~ 11
5. Sharon	~~1111~~
6. Pat	~~1111~~ 1

Figure 5-1. Tally Method Evaluation Form

Another possible model instrument that is designed to get feedback from the participants themselves, not just the evaluator, is shown in Figure 5-2. You or a small-group evaluator might then compile group data on a graph to better observe the total range of responses.

Other evaluation forms might help group members assess their own participation over time or test the affective dimensions of the discussion (particularly when decisions or value judgments are made or data interpreted). Figure 5-3 could be used during a science discussion that focuses on value-laden ideas or decision making.

Directions: To evaluate your group, place an "X" on the line above the statement that best describes your reaction to each of the incomplete sentences.

Group ____________________ Date ______ _

Name ____________________

1. I thought that the discussion

Gave everyone a chance to participate freely.	Allowed almost everyone a chance to participate freely.	Was dominated by only a few.

2. As far as my participation in the discussion, I

Was really with it.	Could have done better.	Was totally out of it.

3. The discussion leader

Encouraged a wide range of participation.	Selected only a few persons to participate.	Seemed to dominate the discussion most of the time.

Figure 5-2. Checklist for Discussion

Directions: The student who evaluates the discussion should circle the response that describes the conclusion. If any negative evaluations are given, then a short statement of how that aspect can be improved must be given.

1. To what extent was the task clearly defined?	Well defined	Somewhat defined	Needed clarification
2. Were all conclusions definitely stated or identified?	Very well stated	Somewhat stated	Suggestions to improve
3. How would you rate the value of the conclusions?	Very practical	Somewhat practical	Impractical
4. Were the conclusions made in light of the problem?	Yes	Some were, some were not conclusions made by considering other data	
5. How well did the group share information?	Much sharing	Some sharing	There seemed to be a need for more
6. To what extent could you determine if the participants were pleased with the manner in which the discussion took place?	All seemed pleased	Most seemed pleased	There seemed to be a mix of feelings

Figure 5-3. Discussion Product Appraisal Form

You evaluate discussions to collate data on how well the processes are going. In this respect they are formative, i.e., used to make adjustments so that everyone becomes a full partner in learning.

In General

The use of small groups in science instruction is one more method by which to make your class more self-sustained. The technique is not to be construed as an "easy way" our of teaching science. After reading the text to this point, you must surely be asking, "Can anyone possibly have the time to do all this and teach science, too?"

The response to that thought is that both science and discussions are chiefly processes. As you teach one process, you integrate the other. Our point of view is that teachers should realize that science is easily adapted to any reasonable teaching technique. Further, by developing small-group discussion strategies, you will find that you will have more time to interact with your class members. It will be, of course, an interaction with small groups--but it does increase your interaction significantly.

Now let us focue on a technique closely related to discussion, but in different dimension -- cooperative learning.

Cooperative Learning

Cooperative learning has been studied for several years by Roger T. Johnson and David W. Johnson. Recently, the National Council for the Social Studies hailed their work as the most important advance in the past two decades! The Johnson's classify instructional goals into three broad categories based on: (1) competition, (2) individualization, and (3) cooperation. Competition is the hallmark of American education (and its business practices). Students compete against each other for grades, learning, resources, rewards. There are a few winners and many losers. You are one or the other! Individualization allows students to work alone, at their own pace and they do not interact socially. But, individualization has not truly shown to help in developing socialization or cognitive development.

Cooperative learning, however, is a process that allows a small group of children to work together to solve a given problem. Studies analyzed by the Johnson's indicate that cooperative learning promotes higher student schievement than do either individualized or competitive learning! This finding undoubtedly will shock most readers. The Johnson's imply that cooperative learning could almost have as great an impact on achievement as does tutoring.

What is important to recognize is that students in cooperative learning situations gain in conceptual and problem-solving skills. Further, these students retained the information longer and developed more positive attitudes toward science. These conclusions are important for prospective and practicing teachers alike.

Structuring for Cooperative Learning

The discussion strategies presented earlier basically incorporated into the cooperative learning model. For example, groups are assigned in two's or four's. Materials are arranged to increase student-student interactions. Then, a task is given that requires each group member to cooperate and shape data. Usually, one report per group is required. That report must accommodate any individual differences.

An adaptation is to have individuals conduct their own "experiments" and then combine as a group to share findings. In this technique, the individual findings are compared to the group's. In many cases, group findings will be more appropriate.

Of course, the teacher constantly monitors group interactions. The sample observation tools illustrated in figures 5-1, 5-2, and 5-3 are all useful. Monitoring groups is critical. If arguments break out, then the teacher helps resolve issues and reminds the students that individual views are important. And the group is reminded that their report is to be a group effort, not four independent reports.

Adapting for Cooperative Learning

To adapt specific lessons that stress cooperation, a teacher modifies a lesson so that there are specific individual tasks that must be done so that all group members may proceed. For example, in the conducting of any activity as division of tasks is made.

As an activity proceeds, a teacher can structure some "time out" periods where each member of the group summarizes what is taking place. This feature enhances understanding.

As work proceeds students are encouraged to learn from each other and to shape their new ideas for further expansion of the idea.

The group product is evaluated as a team, not an individual effort. However, tests are given to each individual. The group does not colloborate on summative evaluations. They should be encouraged to cooperate on formative measures.

Conclusion

The use of small groups and cooperative learning strategies is emerging as a powerful classroom tool. In the long run, these methods reflect how scientists act. Scientists work individually and on teams. Actually, in industry, team work has lead to major scientific and technological truimphs. Nothing in these techniques can be construed as working against individual initiative. Conversely, individuals learn to learn and work as a team. If team spirit is "American" for football, it ought to be the same for learning science!

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CHAPTER 6

USING THE REAL STUFF OF SCIENCE: INQUIRY

Traditionally, teachers at all levels emphasize bodies of knowledge, the content of which becomes both a means and an end in education. Is it any wonder then that hundreds of thousands of students get bored by the routine lectures or recitations? We would like to offer you an alternative teaching technique that is not new but centuries old. The generic term for the technique is inquiry. You may find it referred to in the literature as inquiry, enquiry, discovery, problem-solving, reflective thinking, inductive teaching, or other terms. We will discuss the generic techniques and point out the major differences among them.

Understanding the Concept of Inquiry

The concept of inquiry is rather difficult to define in nonoperational terms--that is, without giving precise examples of teacher strategies and the concomitant student behaviors. As we develop a spectrum of inquiry-teaching options, we will demonstrate their operational meanings by example. Inquiry processes require a high degree of interaction among the learner, the teacher, the materials, the content, and the instructional environment. Perhaps the most crucial aspect of inquiry is that, as it is defined in the dictionary, both student and teacher become persistent askers, seekers, interrogators, questioners, and ponderers and ultimately pose the question that every Nobel Prize winner has asked: I wonder what would happen if . . . .

Of course, we do not expect all of you to make internationally significant discoveries, although we would like to see a few of your students do so. What is important is that you as the classroom teacher set the stage for the process of inquiry to take place. In short, you make the difference. You decide how much time will be spent developing the many processes that reinforce inquiry behaviors. You make the decision to try another method of teaching units of instruction that lend themselves to inquiry processes. You are the one who systematically will teach your students how to ask questions.

Questioning plays a crucial role in both the teaching and learning acts associated with the inquiry mode of learning. Questions lead to investigations that attempt to solve a well-defined aspect of the question. Such investigations are common to all areas of human endeavor. The investigative processes of inquiry involve the student not only in questioning, but also in formulating the question, in limiting it, in deciding on the best methods to use, and in conducting the study.

Lest you be a bit dubious about this method, let us assure you that we view the techniques of inquiry as one more option that is available to you as you establish your own teaching styles.

The emphasis on inquiry instruction seems to be a twentieth-century phenomenon. Perhaps the prime advocate for its wide acceptance is none other than John Dewey. This may surprise you, for in most textbooks and lectures and in the common press the late John Dewey seems to be blamed for every conceivable ill that has befallen our sshools - which is utter nonsense. We will explore the contributions of Dewey as they pertain to problem-solving. You may be surprised to learn that it was Dewey's ideal that became popularized in a conference of scientists, leading to the publication of Jerome S. Bruner's (1960) now classic The Process of Education. This brief historical background on the inquiry process is essential to avoid the same fallacious thinking of which thousands of teachers have been guilty because they were not fully aware of the foundations of inquiry.

As we mentioned, inquiry is an old technique. The distinguished trio of ancient Western culture--Socrates, Aristotle, and Plato--were all masters of the inquiry processes. One can argue that the processes they used have since affected the way most people in our Western civilization think. That heritage has given us a mode of teaching in which students are vitally involved in the learning and creating processes. It is through inquiry that new knowledge is discovered. It is by becoming involved in the process that students become historians, scientists, economists, artists, business-persons, poets, writers, or researchers--even if only for an hour or two in your class.

What then are the basic processes of inquiry? Let us reexamine the thirteen major processes from the elementary science program called "Science: A Process Approach." Briefly, they are: observing, classifying, using numbers, measuring, using space/time relationships, predicting, inferring, defining operationally, formulating hypotheses, interpreting data, controlling variables, experimenting, and communicating.

We are stressing science methods, but we challenge you not to find elements of these thirteen "scientific" processes in every discipline. We submit that even poets use some of them. The main point that we are developing laboriously is that inquiry is not simply the asking of a question; it is a process of conducting an investigation (see Fig.6-1). A similar chart can be constructed easily for selected aspects of literature, art criticism, homemaking, first aid, and many other nonscience subjects.

It is extremely important to understand that each of those processes associated with inquiry must be carefully developed and practiced in a very systematic manner. This requires that the teacher decide how much of each lesson will be devoted to cognitive-skill building and how much to process building--just as with the process of building small-group discussions.

Finally, both the teacher and the students must become aware that the processes must be learned, practiced, demonstrated, and assimilated into the students' learning styles. Of course, the teacher must know the processes and must know how to establish learning situations that will aid in their application. The inquiry processes are most effective when they are internalized by each and every student. We do imply that every student can learn the fundamental processes of inquiry, although this does not mean that every student will demonstrate the same quality of inquiry. In our experiences, we have observed that the "slow" students enjoy using the inquiry processes as much as the very "best" students.

Identifying a problem	Being aware of something
Preparing a statement of research objectives	Proposing testable hypothesis
Collecting data	A. Gathering evidence B. Conducting an experiment C. Surveying a sample
Interpreting data	A. Making meaningful statements supported by data B. Testing hypotheses
Developing tentative conclusions	A. Establishing relationships or patterns B. Specifying generalizations
Replication	A. Obtaining new data B. Revising original conclusions C. Continuous testing.

Figure 6-1. A General Model of Inquiry

Finally, both the teacher and the students must become aware that the processes must be learned, practiced, demonstrated, and assimilated into the students' learning styles. Of course, the teacher must know the processes and must know how to establish learning situations that will aid in their application. The inquiry processes are most effective when they are internalized by each and every student. We do imply that every student can learn the fundamental processes of inquiry, although this does not mean that every student will demonstrate the same quality of inquiry. In our experiences, we have observed that the "slow" students enjoy using the inquiry processes as much as the very "best" students.

As one more way to learn, inquiry provides a dimension to the classroom environment that no other teaching method can--the excitement of learning something that just might not be in the textbook.

The "Professional Bag of Skills"

The following inquiry methods will be discussed next:

1. Inductive inquiry.
2. Problem-solving.
3. Discovery learning.

4. The Suchman Inquiry Model.

For each kind of inquiry presented, you also will be given examples of that style as it is applied in the classroom.

Inductive Inquiry

Let us begin with a caveat: There is no pure inductive-inquiry teaching mode. Basically there are elements of the inductive method that prevail with all inquiry strategies. But note well that inductive teaching methodologies may or may not be true extensions of "discovery." What then constitutes inductive inquiry? Induction or inductive logic is a thought process wherein the individual observes or senses a selected number of events, processes, or objects, and then constructs a particular pattern of concepts or relationships based on these limited experiences. Inductive inquiry, then, is a method that is used by teachers when they present sets of data or situations and then ask the students to infer a conclusion, generalization, or a pattern of relationships. It is a process that allows the student to observe specifics and then to infer generalizations about the entire group of particulars.

Inductive inquiry may be approached in at least two different ways: (1) guided; and (2) unguided. Lee S. Schulman and Pinchas Tamir (1973) provided an easy-to-use matrix illustrating that _if_ the teacher wishes to provide the basic elements of the lesson--that is, the specifics--but wants the students to make the generalizations, _then_ the teacher is conducting a guided inductive lesson. If the teacher decides to allow the students to provide the cases and to make the generalizations, the process may be labeled unguided inductive inquiry. Such a distinction between guided and unguided inductive inquiry is very essential. In most cases, the teacher will begin to build the processes of induction through a set of guided experiences. In this manner, the teacher knows that there is a fixed number of generalizations or conclusions that can be reasonably inferred. The teacher can then go about helping various students to make the observations that lead to these conclusions. In our experiences with inductive inquiry, the guided method provides an easy transition from expository teaching to that which is less expository. This point will be discussed later.

Inductive inquiry is appropriate at all levels of instruction, from pre-school to university graduate schools. Obviously the kinds and quality of induction will vary considerably. An important aspect of inductive inquiry is that the processes of observation, inference, classification, formulating hypotheses, and predicting are all sharpened (or reinforced) by the experiences.

Guided Inductive Inquiry

The use of pictures is usually the easiest way to introduce the initial elements of guided inductive inquiry. As one example for younger children, different pictures of the same scene are shown to the class. The teacher selects these based on the fact that they illustrate some of the differences associated with the seasons. Thus, four typical or even stereotypical pictures are used to show spring, summer, autumn, and winter.

Before beginning the lesson, the teacher will arrange to have all of the necessary materials so that the children are all given materials from which to have similar experiences. In conducting this lesson, the teacher will make extensive use of question-asking skills. The teacher will ask the children to make observations about what they see in the pictures. As the children venture their responses, the teacher must be careful to distinguish between statements based on observations and those based on inferences. When an inference is stated, the teacher should simply ask, "Is that an inference or an observation?" (Of course, the lesson should begin with the concepts of processes of observations and inferences presented in the simplest manner.) As the class progresses, the teacher will prepare a simple chart or will list on the blackboard the actual observations and the accompanying inferences. Each process will be built slowly and carefully with many such examples.

To get students in the habit of being systematic, and this applies to all grade levels, ask each one to write the observation and beside it the inferences. This method also aids you in checking the observations that are the bases for any inferences. Of course, the latter technique cannot be used in kindergarten, grade 1, or even grade 2. In those cases, you can do the writing--or create a pictorial display of student observations and inferences. Of course, prior lessons with appropriate activities would have established the processes of observing and inferring.

As the class progresses, prepare a simple poster or use the chalkboard to list the actual observations and the accompanying inferences. Each process is slowly and carefully built with many examples drawn from actual experiences.

Patterns that the students observe are stated by them as generalizations that apply whenever the pattern is repeated. Thus, the process of inductive reasoning is gradually developed. Try to conduct guided inductive inquiry exercises whenever any occasion arises. Use simple experiences: "What could cause this type of track in the snow?" and "Where have we seen this before?" and "If we had to generalize about the sizes of these leaves, what one sentence could we make?" are the kinds of questions that require the learner to do the generalizing. In this manner you will seldom state the original generalization. You will, or course, be the one who plans for them. These are the kinds of questions that require the child to do the generalizing rather than the teacher to simply present in generalizations.

In guided inductive inquiry, the teacher cannot expect the students to arrive at particular generalizations unless the learning activities, classroom recitations or discussions, learning materials, and visual aids are all arranged so that everything is available to the learner to make the generalizations. Perhaps these initial experiences can even utilize some small groups, such as task groups.

At all levels, the teacher should ask each student to write down the observations and, beside them, the inferences. In this fashion, the student will gain the habit of becoming systematic. This method also helps the teacher to check the observations that were the bases for any inferences.

Inferences

An inference is an interpretation or evaluation that results from making observations of objects or events. When you assemble a series of objects and ask the students to make generalizations about them, they will probably provide inferences. However, an inference is different from a generalization in that a generalization explains or summarizes some verifiable element.

For example, if you give students a big box of buttons and ask them to arrange the buttons according to some classification scheme, they will arrive at several different classes of buttons. They will also observe some trait that is general to all buttons in the group--three holes, shanks, shankless, round, square. If you ask for possible uses of the different buttons, you then approach the inference-building stage. The students begin to speculate about uses. But you ask other questions, such as "How could we find out?" or "Is that button big enough for an overcoat?" By asking your students to provide evidence or examples of how to test their ideas, you will help them reach the inference-building stage.

The Time Involved

When you initially utilize any type of inquiry activity in your classes, you must plan to spend at least twice the amount of time on each lesson than you would normally expect. Any inquiry activity takes time to plan, initiate, and complete. This greater time use is spent on in-depth analysis of the content by the students, i.e., true understanding.

Furthermore, the use of inquiry methods requires greater interaction between the learner and the materials. There is also greater interaction between the teacher and the students. However, there is a small amount of risk involved for the students. They will not have an authority or book to memorize, but must rely on their own data or observations. You will find that most children and adults approach inquiry activities with a great deal of caution--if not apprehension. But as the inductive-inquiry activities become a part of the ongoing procedures of the class, learner apprehension diminishes.

Another caveat is required: When you use an inquiry method, the amount of material covered is actually reduced. The reason is that you are using more time to develop thinking processes and reducing the time spent on memorization of fact or content. You cannot maximize thinking skills and simultaneously maximize content coverage. If you wish to build the so-called higher-order thinking skills, then you must reduce some of the content and substitute processes instead. In fact, you are not sacrificing anything. You are providing important instruction and experiences that are a part of the function of understanding the structure (epistemology) of the disciplines. The decision to follow this approach is yours. *Your* role is therefore very important.

In lower grades or when conducting initial experiences, the final generalization(s) may involve an oral summary or review of the concepts, a listing of the ideas presented, and finally, the eliciting of the learners' own views as to what constitutes a meaningful generalization. As the learners provide statements, the teacher should use such questioning techniques as probing, concept review, and prompting.

The testing of the generalizations can be accomplished by having the class apply the statement to different times, places, peoples, objects, or events. A major limitation of the testing will be the backgrounds and experiences of the learners.

Another technique that may be used with guided inductive inquiry is to write down a series of events on cards or on some other manipulative medium. Then ask the learners to place the events in the "proper" sequence, without any reference to the order being right or wrong. This activity can follow a reading assignment. When the sequence of events is completed, ask the students to observe the pattern of events and to state the pattern in just one sentence. This sentence will be the generalization. Other members of the class can be asked to test the generalization by examining it for significant exceptions. Another excellent technique to be used here is "cooperative learning." Inquiry activities lend themselves most appropriately to cooperative learning.

These suggestions provide some tested models that help students to think inductively--that is, to infer generalizations. These models are adaptable to all levels of instruction. The efficiency of the learners--and of the teacher--will improve with practice.

Analysis of Guided Inductive Inquiry

As you read the previous presentation, you probably noted that we did not have any set prescription or rules to follow. The model illustrated in Figure 1 shows five major steps in that inquiry system: (1) defining the problem; (2) developing tentative answers; (3) testing the tentative answers; (4) developing a conclusion; and (5) applying the conclusion. Implied in such a model is that the student finds the problem, or at least recognizes it, and then follows the five steps to attempt to resolve it. In nearly all cases data will be collected or some materials will be manipulated.

These steps usually are needed for introductory guided inductive lessons. Recall that the process objectives are to observe, to infer, and to conclude. The problem, if it can be called one, is to determine a meaningful pattern in an array of events or objects. This process is not simply the allowing of wild guesses to take place. All inferences must be supported by some evidence--that is, observations or data. The latter may be obtained from some standard reference source such as the United States Statistical Abstract, or from almanacs, yearbooks, reports, or encyclopedias. The data become the focal point of the inquiry session and thus serve as a common experience for the entire class.

Guided inductive inquiry includes the following characteristics:

1. The thought processes require that the learners progress from specific observations to inferences or generalizations.

2. The objective is to learn (or reinforce) processes of examining events or objects and then to arrive at appropriate generalizations.

3. The teacher controls the elements--the events, data, materials, or objects--and as such, acts as the class leader.

4. The student reacts to the specifics of the lesson--the events, data, materials, or objects--and attempts to structure a meaningful pattern based on his

or her observations and on those of others in the class.

5. The classroom is to be considered a learning laboratory.

6. There is usually a fixed number of generalizations that will be elicited from the learners.

7. The teacher encourages each student to communicate his or her generalizations to the class so that others may benefit from individual perceptions.

The use of guided inductive inquiry may or may not be "creative" in the sense of allowing the learners the opportunity to "discover" something new. It can be argued that the process of discovery should be reserved for that which is truly unique in our culture. But such a situation would limit discovery to only the U.S. Patent Office. In schooling, the term discovery can mean that: (1) the student has, for the very first time, determined something unique to that individual; (2) the student has added something to a discussion about a problem that the teacher or other students had not known before; or (3) the student has synthesized some information in such a manner as to provide others with a unique interpretation--that is, the student has demonstrated creativity.

Unfortunately, such a variety of definitions causes disagreements about discovery in the schools. Purists tend to support the third definition. We tend to defend the position that discovery should be reserved for those situations in which problems are being solved and possible solutions or alternatives have not yet been stated. Thus, we support the second definition.

Models of Guided Inductive Inquiry

Two models of guided inductive inquiry are presented here. The first model was initially used in Pasco, Washington, when one of the authors was an instructor on a teacher-aide project. The aides were given the challenge of determining the patterns observed when using the compound microscope, so that they would be familiar with one of the most commonly used pieces of scientific equipment. This exercise has since been used widely at several grade levels. Note how simple such an exercise can be.

The second model, a clever guided inductive devise, allows students to learn about the mixing of colors from their own observations. In this model, note how easy it is to adapt elements of guided inductive inquiry to the fine arts. Another aspect of Model 2 is that it readily lends itself to the use of the overhead projector. Later in this chapter, we will discuss the use of transparencies in stimulating group instruction in an inquiry mode.

Although we have made a strong case for individual work during inquiry sessions, there is nothing wrong with the teacher also presenting a demonstration to the entire class. If the teacher decides to use this technique, then he or she should require that each student write down his or her own observations, inferences, and generalizations, rather than having an oral recitation period. This technique helps each learner to improve in self-reliance. In this manner, each individual can develop his or her own logical framework, which may not be the case during oral recitations. In a group mode, it may even be wise to prepare a handout for the students so that they may record their observations and opinions in a guided, systematic manner. Again, small groups or cooperative learning can be used.

After examining the three models of guided inductive inquiry, try to develop a similar lesson for your teaching area or discipline. Do not make the mistake of saying, "It can't be done for my subject." Thousands of students or teachers in our classes, with majors ranging from art to zoology, have all prepared either a guided or an unguided inductive inquiry lesson.

Model 1 - An Inductive Approach to the Compound Light Microscope

Biology and general science students are usually introduced to the compound microscope through a general discussion or lecture on nomenclature, microscope care, proper use of focusing knobs, lens systems, and the like. They are then given a microscope, a set of slides, clover slips, and other materials needed to complete observation exercises, and are expected to prepare suitable drawings for the teacher's examination.

NOTE: Students are seldom aware that the objects they view are inverted, upside down, or reversed--despite knowledge that movement of the slide causes a reverse action. Furthermore, they are unaware that the focal area is in a plane and that by continual focusing, new planes come into view.

This report describes an exercise needed to give students a better understanding of the compound microscope than they usually acquire through traditional means of presentation. Using an inductive approach, it allows students to make "discoveries" and generalizations about the microscope for themselves. The materials involved are simple and can easily be permanently mounted for classroom use.

Exploring the Compound Light Microscope

Objectives. The purpose of the exercise is to allow students to arrive inductively at the following three generalizations:

1. Objects appear inverted and reversed left to right.
2. The field of observation is inversely related to the power of the lens being used. As the magnifying power of the lens increases, the area of the observed field decreases.
3. Materials can be viewed as three-dimensional objects and are arranged on distant planes.

Use. The exercise is presented here as it was developed and used for a class of teacher aides. However, it is readily adaptable for use with high school students.

Part 1. For the first phase of the exercise--to help students realize the inversion of objects under the microscope and their reversal left to right--several words and other symbols were typed on sheets of cellophane paper, using carbon ribbon to make a dark impression. Initially, one line of typed material was mounted on a posterboard slide having a quarter-inch slit to expose the typed line (see Fig.6-2).

Students were asked to observe the line of characters, especially the question mark, and to draw exactly what they observed under low power, medium power, and high power. When all students had completed their drawings, they were asked to state generalizations concerning what they had observed.

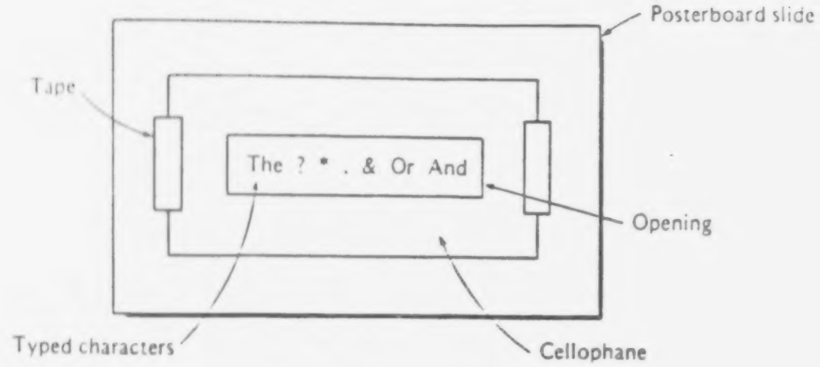

Figure 6-2. Slide Used to Determine Field Area of Magnification and Inversion of Objects

Sample Results. Interestingly enough, during the period several student observed that the object being viewed was upside down. However, these students proceeded to reorient the slide on the microscope stage to give them a "corrected" image! Other students drew the figures as they appeared through the eyepiece--that is, inverted. When asked to make generalizations regarding this phenomenon, all agreed that the objects had been reversed or upside down.

One participant who had recently completed a college biology course was astounded to realize that she had never made this observation in a full quarter of biology lab work. She stated that the slides which she had used were either stained or unstained and unprepared but that at no time had she realized inversion took place, and that no one had ever mentioned this in class--including the instructor.

Part 2. The second part of the exercise, seeking generalizations relating field size to the magnifying power of the lens, was difficult for many students to comprehend immediately. However, on repeated observation, without the instructor telling them what they should observe but with leading questions, those who had difficulty were able to state that "you cannot 'see' all of the letter under the highest power that you can see under the lowest power."

Part 3. The third objective--to have students observe that the field is arranged in planes--was achieved by using overlapping pieces of cellophane with type-on letters and other symbols. The letters on one sheet were typed with a red ribbon, those on the other with a black ribbon, so that each plane of focus would be observable even though the planes overlapped (see Fig. 6-3).

NOTE: While students can obviously be "told" about these phenomena, telling students is not as meaningful as helping them to make the "discoveries" themselves using an inductive method similar to that described here.

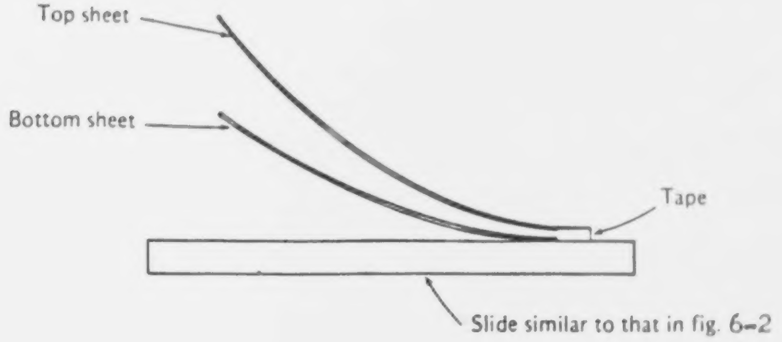

Figure 6-3. Side View of Slide Illustrating Two Viewing Planes

Model 2 - Color Wheeling and Dealing

The usual approach to teaching the color wheel tends to be rather mechanical, requiring little discovery on the student's part and, most of the time, involving only memorization of concepts and principles. A more inquiry-oriented approach would be to allow the student, through a guided inductive inquiry experience, to observe visually what happens when primary colors are mixed.

This model comprises a very simple device that is prepared by using three sheets of transparency film. The three sheets are in the primary colors of blue, yellow, and red. They first are identified and then are arranged in a circle so that each third of the circle contains one of the three transparency films. The teacher then displays them on an overhead projector and defines them as the primary colors. A separate set of blue, yellow, and red wedges are prepared so that the teacher may direct student observations that help them to learn about color mixing.

Objectives. This device is designed to allow students, through observations, to arrive at the following conclusions:

1. Blue + Yellow = Green
2. Blue + Red = Purple
3. Red + Yellow = Orange
4. Orange + Blue = Brown
5. No other color combinations will produce the secondary colors.

6. The lightness of a color is a function of the thickness or concentration of the overhead transparency film.

Procedures. The teacher prepares a color circle that contains the red, yellow, and blue transparency films. These films are then shown to the students so that they will know that they represent the three primary colors. The students are then asked to predict what might happen if the red and yellow films were superimposed on each other and to write down their responses. The teacher then lays the red strip on the yellow strip, or vice versa, and the students observe the resultant orange color.

The teacher next asks the question, "Does it make any difference whether the red or the yellow transparency is on top of or under the other?" The students make predictions, and the teacher places the red film on the yellow, and the yellow on the red. The students then generalize that it makes no difference which color is placed on which, since orange is always produced when red and yellow are mixed.

The teacher repeats the same procedure using blue and yellow and asks the students to make predictions. The teacher lays a blue strip of overhead transparency film on a yellow strip and, of course the result is green. The teacher reverses the order, superimposing a yellow strip on a blue strip. The students are again asked to predict the color. Again, it is shown to make no difference which strip is placed on which, for the resultant color is always green. The teacher does the same operation using blue and red transparency film wedges, with the resultant color being purple.

The teacher then displays the orange color, which was made by mixing the red and yellow strips of film, and asks the student to predict what would happen if blue were superimposed on it. After the predictions are made, the teacher lays the blue strip on the orange color, producing a brown color. The teacher then proceeds to mix various transparency colors so that from the primary colors the secondary colors of orange, violet, and green are created. During the entire procedure, the teacher repeatedly asks, "What would happen if we mixed these colors?" The students make predictions, make observations, and change their predictions based on their observations.

The full color wheel may be impossible to make unless a complete set of overhead transparency films is available. However, a very close approximation of a color wheel can be made to show complementary colors.

The important aspect of this guided inductive device is that students are given an experience that requires them to make observations and to change their predictions based on these observations. Furthermore, the students will observe that the amount of light coming through seems to be reduced as the colors are mixed. The teacher may ask for explanations for this phenomenon (that more light is absorbed with darker mixes). The relationship between the amount of light and the darkness of a mix, as well as the relationship between the amount of light and "concentration," may be discussed.

Another procedure that can be tried is to use solutions of water and food coloring to demonstrate the three primary colors. The water, contained in separate small glass dishes, may be placed on the stage of an overhead projector. The teacher may then drop the food coloring into the water, or the students may be asked to mix the colors. The teacher can set up an experiment in which concentrations of the food coloring may be one variable and the amount of water the other. In this case, sets of identical containers will have varying depths of water but the same number of drops of food coloring. The students are asked to arrange the containers in some type of observable pattern, and then to explain by what variable the containers are arranged. The expected response will be that the darkness or lightness of color is the variable used. The teacher then asks the students to try to match the darkness or likeness of the colors. The students then prepare different sets of solutions with varying color darknesses. In all cases, the students will collect data concerning their observations and the techniques being used.

Depending on how the teacher wants the color-mixing inductive technique to be conducted, students will probably make a chart that will show the following: (1) the number of drops of food coloring in a specific volume of water: and (2) the number of drops of food coloring in different volumes of water. The students will then begin to discover the concept of concentrations being based on the operational definition of lightness.

This model of guided inductive inquiry can be controlled entirely by the teacher, or the students can be involved in conducting all of the trials. The essential elements of inquiry are integrated into the lesson, and the students become more active in a topic that usually does not require involvement. The students can even suggest additional "experiments." However, the teacher has the choice of using either a dry medium (that is, transparency paper) or a solution, depending on the medium being used by the class. But in either case, the students will have learned a useful inquiry technique while "color wheeling and dealing."

Questioning and Guided Inductive Inquiry

We have noted that teacher questioning plays an important role in inquiry, because the purpose of inquiry is to pursue the "search," the "investigation." To accomplish this purpose, the teacher becomes a question-asker, not a question-answerer. Teachers who are masters of guided induction inquiry will state that they spend their time interacting with students but provide very few answers.

What kinds of questions should a teacher ask? Orlich and James M. Migaki, have categorized several "stems" or lead-in questions for teachers who want to have a more inquiry-oriented class environment. Of course, what makes the set of stems so interesting is that they are especially suitable for use in social studies, science, and mathematics. But they are usable in *any* class in which the teacher wants to stress the process of inquiry.

If you are conducting an experiment, collecting data, examining cause-and-effect relationships, or analyzing events, then the following set of question stems are very appropriate for challenging the student to think.*

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*The two sets of question stems are reprinted with the written permission of The National Science Teacher's Association. From: Donald C. Orlich and James M. Migaki. "Watch your IQQ--Inquiry Questioning Quotient," *Science and Children*, May, 1981, *8*, 20-21.

What is happening?
What has happened?
What do you think will happen now?
How did this happen?
Why did this happen?
What caused this to happen?
What took place before this happened?
Where have you seen something like this happen?
When have you seen something like this happen?
How could we make this happen?
How does this compare with what we saw or did?
How can we do this more easily?
How can you do this more quickly?

Note that this list is oriented to dynamic situations. You may even think of a few more questions to add for your own specialty or grade level. These stems are probably best classified as prompting questions, similar to those described in Chapter 4.

If you are examining more static living or nonliving objects, the following stems will prove very useful.

What kind of object is it?
What is it called?
Where is it found?
What does it look like?
Have you ever seen anything like it? Where? When?
How is it like other things?
How can you recognize or identify it?
How did it get its name?
What can you do with it?
What is it made of?
How was it made?
What is its purpose?
How does it work or operate?
What other names does it have?
How is it different from other things?

Again, note that these prompting questions help the student to understand better all kinds of interrelationships, which is one of the desired goals of inquiry teaching.

To elaborate on the role of questioning and process-building the teacher of younger students can use a series of pictures about where people live. This guided inductive-inquiry project would be ideal in a science class. The materials would consist simply of pictures of various "typical" houses of the world, which can be obtained from magazines. If you have no sources of such pictures, just ask the students to bring in old magazines from their homes or from the neighbors. In no time, you will have accumulated a lifetime supply.

There are several ways you can approach this lesson. The first may be to select houses that all have some similar trait--for example, steep roofs, flat roofs, white paint. The objective is to get the students to observe patterns, similarities, and differences--Again "process as content."

As a preliminary activity, you can conduct a recitation involving the whole class. (Later, we would prefer you to subdivide the class into groups of eight, so that students may practice those discussion skills or cooperative learning previously presented. Have the students observe the pictures while you list their observations on the chalkboard or, better yet, on newsprint. By using the latter, you can tape the newsprint to a wall and place the pictures on a table next to it, thus allowing the students who did not seem to master the process of inductive logic to practice more on their own. But let us return to the lesson.

You may need to ask a series of questions about the houses, the land, and other observable elements in the picture. Then you begin to build toward a general statement regarding all the pictures being studied. When this statement is made by the class, successful guided inductive inquiry is demonstrated. The lesson can be reinforced by using other objects such as leaves in the fall, old buttons in the winter, mittens, whether or not the children wear mittens, the children's feet, their hands, their earlobes--any objects that can be classified, sorted, counted, or contrasted. It is essential to keep reinforcing the learning wherever possible simply by asking, "What do we observe here?"

The teacher with any initiative can use this type of lesson at higher grade levels. For example, junior high students can determine the relative standards by which houses are built in different areas of the world and the reasons for the discrepancies. High school students can be challenged to compute the energy costs of heating or cooling systems and the effectiveness of insulation in conserving energy. The teacher is thus the organizer and expediter of guided inductive inquiry, while the students are the active thinkers and doers.

Unguided Inductive Inquiry

In the preceding text concerning guided inductive inquiry, the teacher played the key role in asking the questions, prompting the responses, and structuring the materials and situations, and in general was the major organizer of the learning. Guided inductive inquiry is an excellent method by which to begin the gradual shift from expository or deductive teaching toward teaching that is less structured and more open to alternative solutions. If the teacher senses that the class has mastered the techniques of guided inductive inquiry, then the teacher ought to introduce situations that are still predicated on inductive logic but are more open-ended in that the students must take more responsibility for examining the data, objects, or events.

The basic science processes of observation, inference, classification, communication, prediction, interpretation, formulation of hypotheses, and experimentation are all a part of unguided inductive inquiry. The teacher's role is minimized, which causes a concomitant increase in the students' activity. Let us briefly summarize the major elements of unguided inductive inquiry.

1. The thought processes require that the learners will progress from specific observation to inferences or generalizations.

2. The objective is to learn (or reinforce) the processes of examining events, objects, and data and then to arrive at appropriate sets of generalizations.

3. The teacher only controls the materials and simply poses a question such as: "What can you generalize from . . . ?" or "Tell me everything that you can about 'X' after examining these. . . ."

4. The students interact with the specifics of the lesson and ask all of the questions that come to mind without further teacher guidance.

5. Meaningful patterns are student-generated through individual observations and inferences, as well as those generated by others in the class.

6. The materials are essential to making the classroom a laboratory.

7. There is usually an unlimited number of generalizations that the learners will generate.

8. The teacher encourages a sharing of the inferences so that all students communicate their generalizations with the class. Thus, others may benefit from one individual's unique perceptions.

Unguided inductive inquiry provides a mechanism for greater learner creativity. Also, the learners begin to approach a genuinely authentic discovery episode. For, as Kenneth A. Strike (1975) has argued, discovery learning is approached when learners find out something by themselves and come to know that fact. Strike refers to this process as relative discovery--that is, the event may have been known to others prior to the time the learner discovered it by himself or herself.

When the teacher begins to use unguided inductive inquiry, a new set of teacher behaviors must come into play. The teacher must now begin to act as the "classroom clarifier." As students begin to make generalizations, predictably errors in student logic will appear, students will make too broadly stated generalizations, infer too much from the data, assign single cause-and-effect relationships where there are several, and assign cause-and-effect relationships where none exist.

Thus, the teacher patiently examines the learner in a nonthreatening manner to verify the conclusion or generalizations. If errors exist in the student's logic or inferences, these should be pointed out. But the teacher should not tell the student what the correct inference is, for this would defeat the purpose of any inquiry episode.

We suggest that during initial unguided inductive experiences, the students should work alone. However. research by Johnson and Johnson does support students working in pairs or triads, where group members share the leadership roles. A group report then makes it essential that the group cooperate. Students who quickly demonstrate an aptitude to use the inductive method successfully in an unguided fashion can be assigned to act as tutors for those having trouble.

Some Unguided Inductive Inquiry Techniques

What are some tested ideas that can be used as prototypes to encourage teachers to seek appropriate inductive learning experiences that can be incorporated into an ongoing lesson? Below are but a few activities.

1. Collect several dandelion flowering heads. Count the number of parachute seeds on each. Make a graph of the results for each flower.

2. Measure the height of some local weed as it grows in the shade and as it grows in the sunlight, and compare those findings.

3. Count the number of leaves on the limb of a small tree.

4. Count the number of vehicles that pass a specific point during a given hour. Then recount the number of vehicles that have only one person--the driver. Then count the number of vehicles by types--large cars, small cars, trucks.

5. Tabulate the highest and lowest temperature readings for several cities for a month or even a year.

6. Count the number of persons who pass a given point in the school lunch line.

7. Tabulate the exact number of minutes that commercials appear on given television shows.

8. Count the number of windows that can be seen in all the houses on one block.

9. Tabulate the number of clear-sky days your town has. Share this information with some school in another city in a different part of the country. To initiate these activities you could have the students make a list of possible hypotheses.

The advantage of these activities, is that they can all be tested. The students do research to verify their hypotheses. They soon realize that their hypotheses are untenable. The reality dimension of such inquiry exercises helps to develop logical processes in the child's method of looking at nature.

These data inquiry challenges can be great stimulators of classroom discussions. Data exist for every grade level experience and for every possible subject, ranging from art to zoology. It is also possible to present data in such a way that students must either interpolate (predict what should have come earlier) or extrapolate (predict later outcomes). Teachers can control the flow of data (information) so that predictions may be made and justified. Evidence, facts, and their interpretation all become more meaningful to the students instead of being merely words in a book.

With the passage of PL 94-142, all teachers at all grade levels will have learning-disabled students--in some cases, mentally or emotionally retarded students--as members of their regular classes. These students will need to use tangible tools to learn the fundamentals of inquiry. This requires that teachers prepare added sets of materials for these students. We frequently prepare graphs for the overhead projector so that a group may work together in the process.

Lest you become discouraged, remember that not all "regular" children will be at the same learning status either. Students regularly transfer in and out of schools. Thus, you must establish mechanisms by which these "transfer" students are quickly integrated into all class activities. You learned about the use of tutorial groups, task groups, and cooperative learning which are techniques that you may employ under these circumstances. Let us expand on classroom transfers. It is not unusual to have a 15 to 30 percent turnover of children in any one class. Some teachers have informed us of over 50 percent turnover. In these classes a cooperative learning strategy might be one that helps newcomers achieve and become involved.

We are suggesting that any teacher at any level has some information that poses questions for which there are no answers. By providing this information to the students, the teacher initiates unguided inductive inquiry. To be sure, we do not assign exercises just for the sake of having the students do them. Exercises must be correlated with the learning objectives or goals that *you* have selected for the unit, chapter, or module. Some topics lend themselves easily to inductive inquiry while others do not. *You* must decide on these topics.

For example, Russell M. Agne (1969) of the University of Vermont uses original data in the teaching of earth science. He presents radiosonde data in tabular form, providing learners with the barometric pressures for various altitudes in one-kilometer increments. The learners are given both guided and unguided exercises to complete. Other original data provided by Agne include temperatures at varying altitudes, solar radiation data, mean annual temperatures, and other "real" data.

Again, a word of caution must be mentioned. You do not suddenly begin to use inquiry without preparation. You plan for experiences that are meaningful and relevant. For language arts classes, the local newspaper is one of the finest and cheapest resources for raw data. Have the students examine the news stories of the local "scandal sheet" as well as those of various cities around the state or country. Let them make generalizations about such matters as editorial positions, the use of propaganda and persuasive techniques, and the ways of slanting (or biasing) stories--on science related issues, of course.

Although we have not emphasized the process of classification in the inquiry modes, we wish to mention that, as humans, we constantly classify everything in our lives--such as people, objects, baseball games, suits, houses, cars, movies, and TV shows. One of the generalizations that will quickly emerge as you use inductive modes is that there is no one way to classify anything. Your students will arrive at usable classification schemes that you may not have thought existed.

One of our favorite classification exercises involves the "old button box" device. Obtain as many buttons as you can from a "scavenger hunt" and place them in a bag. Then ask each class member to establish a classification scheme for the buttons that he or she has. We guarantee that you will be surprised at the number of characteristics that the students will observe as being useful in classifying their buttons.

Classification exercises can lead to some elements of evaluation as we know it in Bloom's Taxonomy. Evaluation, as you recall, is conducted using explicitly stated criteria. But how does one classify or evaluate the criteria? Utility has to be one consideration. There are others, but allow the students to determine them for themselves.

About the Inductive Method

Perhaps you have been taught that the inductive method of inquiry is "the method of science." If so, you have been somewhat led astray. To be sure, scientists use inductive methodologies. But detailed analyses of scientific thought by Karl R. Popper (1959; originally published in 1934) and, more recently, by Thomas S. Kuhn (1962) show that modern science is characterized more by *hypothetico-deductive* reasoning than by pure inductive logic. However, inductive logic is a basis for inference building, and scientists typically rely on theories or working hypotheses on which to base their "inductive experiments." This means that modern-day empiricism is undergirded by theoretical propositions. Actually, Popper argues that there is no such thing as theory; there are only testable hypotheses. The longer a hypothesis stands the tests of experimentation and predictability, the more it gains "respect" in the scientific community. Emerging social science fields such as sociology, psychology, and anthropology, to list three, are now developing substantial bodies of testable theory--that is, working hypotheses. The worth of any theory or hypothesis is its ability to predict future events. The so-called hard sciences--chemistry and physics--have had a long tradition of hypotheses that have stood the rigors of experimentation and prediction. Physicists and chemists proudly state that without the strong theoretical commitment those disciplines have, they would be unable to function in the laboratory to conduct systematic research.

Compare this position to teaching or education. In our field, there are few testable hypotheses that can help the teacher to teach better. Thus, the state-of-the-art for education is far behind that of the other social sciences. Perhaps you have complained that education courses "have too much theory." We argue that you have been exposed to too much unconnected, inductive logic in the form of classroom anecdotes, without the necessary theoretical structure.

Problem-Solving

A curricular model that could have had an even greater impact on the schools was that advocated by John Dewey, a seminal writer who published extensively from 1884 to 1948. Among his major educational contributions was his advocacy of a curriculum based on problems. He defined a problem as anything that gives rise to doubt and uncertainty. This theory is not to be confused with the "needs" or "interest" theories of curriculum. Dewey did have a definite idea of the types of problems that are suitable for inclusion in the curriculum. The problems that Dewey promoted had to meet two rigorous criteria: (1) the problems to be studied had to be important to the culture; and (2) the problems had to be important and relevant to the student.

It is very apparent that many curriculum projects developed between 1958 and 1970 in science tended to be based on Dewey's problem-solving approach. Most contemporary curricula and a large majority of textbooks suggest "problems" to be solved by students. Some of the curricula that you may encounter will stress elements of inquiry, discovery, or problem-solving. Contemporary curricula, especially interdisciplinary ones such as environmental studies, rely heavily on the two criteria that were first suggested by Dewey. If you assign "research reports" to be prepared by your students, you will be using elements of problem-solving. Again, we caution that the use of this technique, like any inquiry method, requires careful planning and systematic skill-building.

Understanding the Implications

Implicit within the framework of problem-solving is the concept of "experience." This concept assumes that activities that students attempt under the school's direction will produce certain desirable traits (or behaviors) in those individuals, so that they will be better able to function in our culture. Furthermore, the experiences provided by the schools should articulate the content and the process of knowing. Both knowing what is known and knowing how to know are important objectives for the learner.

Ideally, the learners should independently identify a problem that should be studied, following those steps illustrated in Figure 6-1. For an example, see the following classic illustration of problem-solving taken from a work of that eighteenth-century bon vivant, Jean Jacques Rousseau. In his book Emile, originally written in 1762, Rousseau made a strong appeal for an educational system predicated on, among other criteria, relevant experiences for youth. In one sense, his notions precede those of John Dewey. Quoted here is one episode in which Rousseau and his little charge, Emile, operationally define the solving of a problem.* Note how interestingly the concepts of experience and relevance are blended. For those of you who favor the "open" school, ask yourself whether or not this is an ideal to which you subscribe.

> I do not like verbal explanations. Young people pay little heed to them, nor do they remember them. Things! Things! I cannot repeat it too often. We lay too much stress upon words; we teachers babble, and our scholars follow our example.

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*From Emile by Jean-Jacques Rousseau, translated by Barbara Foxley. An Everyman's Library Edition. Reprinted by permission of publisher in the United States, E.P. Dutton. Permission for Canadian reprinting granted by J.M. Dent & Sons LTD, Publisher.

Suppose we are studying the course of the sun and the way to find our bearings, when all at once Emile interrupts me with the question, "What is the use of that?" What a fine lecture I might give, how many things I might take occasion to teach him in reply to his question, especially if there is any one there. I might speak of the advantages of travel, the value of commerce, the special products of different lands and the peculiar customs of different nations, the use of the calendar, the way to reckon the seasons for agriculture, the art of navigation, how to steer our course at sea, how to find our way without knowing exactly where we are. Politics, natural history, astronomy, even morals and international law are involved in my explanation, so as to give my pupil some idea of all these sciences and a great wish to learn them. When I have finished I shall have shown myself a regular pedant, I shall have made a great display of learning, and not one single idea has he understood. He is longing to ask me again, "What is the use of taking one's bearings?" But he dare not for fear of vexing me. He finds it pays best to pretend to listen to what he is forced to hear. This is the practical result of our fine systems of education.

But Emile is educated in a simpler fashion. We take so much pains to teach him a difficult idea that he will have heard nothing of all this. At the first word he does not understand, he will run away, he will prance about the room, and leave me to speechify by myself. Let us seek a more commonplace explanation; my scientific learning is of no use to him.

We were observing the position of the forest to the north of Montmorency when he interrupted me with the usual question, "What is the use of that?" "You are right," I said, "Let us take time to think it over, and if we find it is no use we will drop it, for we only want useful games." We find something else to do and geography is put aside for the day.

Next morning I suggest a walk before breakfast; there is nothing he would like better; children are always ready to run about, and he is a good walker. We climb up to the forest, we wander through its clearings and lose ourselves; we have no idea where we are, and when we want to retrace our steps we cannot find the way. Time passes, we are hot and hungry; hurrying vainly this way and that we find nothing but woods, quarries, plains, not a landmark to guide us. Very hot, very tired, very hungry, we only get further astray. At last we sit down to rest and to consider our position. I assume that Emile has been educated like an ordinary child. He does not think, he begins to cry; he has no idea we are close to Montmorency, which is hidden from our view by a mere thicket but this thicket is a forest to him, a man of his size is buried among bushes. After a few minutes' silence I begin anxiously--

Jean Jacques: My dear Emile, what shall we do to get out?
Emile: I am sure I do not know. I am tired, I am hungry, I am thirsty. I cannot go any further.
Jean Jacques: Do you suppose I am any better off? I would cry too if I would make my breakfast of tears. Crying is no use, we must look about us. Let us see your watch; what time is it?
Emile: It is noon and I am so hungry!
Jean Jacques: Just so; it is noon and I am so hungry too.
Emile: You must be very hungry indeed.
Jean Jacques: Unluckily my dinner won't come to find me. It is twelve o'clock. This time yesterday we were observing the position of the forest from Montmorency. If only we could see the position of Montmorency. If only we could see the position of Montmorency from the forest--
Emile: But yesterday we could see the forest, and here we cannot see the town.
Jean Jacques: This is just it. If we could only find it without seeing it.
Emile: Oh! My dear friend!
Jean Jacques: Did not we say the forest was--
Emile: North of Montmorency
Jean Jacques: Then Montmorency must lie--
Emile: South of the forest.

> Jean Jacques: We know how to find the north at midday.
> Emile: Yes, by the direction of the shadows.
> Jean Jacques: But the south?
> Emile: What shall we do?
> Jean Jacques: The south is opposite the north.
> Emile: That is true; we need only find the opposite of the shadows.
> That is the south! That is the south! Montmorency must be over there! Let us look for it there!
> Jean Jacques: Perhaps you are right; let us follow this path through the wood.
> Emile: (Clapping his hands.) Oh, I can see Montmorency! There it is, quite plain, just in front of us! Come to luncheon, come to dinner, make haste! Astronomy is some use after all.
>
> Be sure that he thinks this if he does not say it; no matter which, provided I do not say it myself. He will certainly never forget this day's lesson as long as he lives, while if I had only led him to think of all this at home, my lecture would have been forgotten the next day. Teach by doing whenever you can, and only fall back upon words when doing is out of the question.
>
> The reader will not expect me to have such a poor opinion of him as to supply him with an example of every kind of study; but, whatever is taught, I cannot too strongly urge the tutor to adapt his instances to the capacity of his scholar; for once more I repeat the trick is not in what he does not know, but in what he thinks he knows.

The Teacher's Role

When using problem-solving with learners, the teacher must constantly play the "great clarifier" role. The teacher must always help the learners to define precisely what it is that is being studied or solved. Problem-solving methodologies focus on the systematic investigation of the students' problems. The students set up the problem, clarify the issues, propose ways of obtaining the needed information or data to help resolve the problem, and then test to evaluate the conclusions. In most cases, the learners will establish written hypotheses for testing. We cannot overemphasize the fact that students need continual monitoring by the teacher. Problem-solving demands that the teacher continually receive "progress reports" from those students engaged in the investigative process.

Students are not simply allowed to follow their whims. Problem-solving requires the building of close relationships between students and teacher. It also involves a systematic investigation of the problem and the proposing of concrete solutions. Let us present two case histories of real problems that took place in a Boulder, Colorado, high school and in a Massachusetts elementary school.

Examples of Real Problem-Solving

Boulder, Colorado, is situated on the eastern terminus of the great Rocky Mountain Range. The picturesque setting has all the natural beauty that is shown in scenic books and chamber of commerce brochures. Cascading down the mountains is Boulder Creek. It enters the city of Boulder as an uncontaminated, clear, cool stream. Unfortunately, it does not leave in the same state. Awareness of this condition prompted a group of high school students to raise the question: "What are the contributing causes of this problem?" Thus the group went to work in setting up a plan of investigation.

It soon became apparent that the class had to seek help from the chemistry teacher, for if a group is to determine what types of pollutants are present, the water must be chemically analyzed along several points of the creek. This development presented the need for cooperation--that no one person could complete the total investigation alone and that others had to be brought in for "expert" advice. While the chemical analyses were being conducted, another group took a series of temperature readings and depth soundings to determine the temperature fluctuations along the creek's course as it flowed through the city. Other small groups attempted to locate users of the creek's water.

Thus, a heuristic approach was utilized to investigate this problem. By using a heuristic method, the larger problem was subdivided into specific or more manageable components. The authenticity of the problem was apparent, so the teacher did not have to establish the credibility of the study. Furthermore, all student hypotheses could be tested in the real world. The group proposed the ways of obtaining information and then evaluated the worth of the data that had been collected.

To conclude this case study, these students found out that the major polluter of the creek was, in fact, the University of Colorado's maintenance department. The university would simply flood the lawns on the campus, not to drown the Hippies, as one student hypothesized, but to irrigate the lawns in the most economical manner. The only trouble with that system was that it raised the temperature of the water and contributed the nitrates and phosphates that were used to fertilize the lawns. When the final report was duplicated, one copy was presented to the president of the university and another was sent to the local paper. Needless to say, the university changed its watering methods, and the creek was less polluted than before.

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In a similar vein, children in a Massachusetts elementary school collected data and presented it to their local school board showing that at a major intersection there was a grievous safety problem. The students then showed how an overpass walk could be constructed and even contacted architects to obtain estimates of the cost of such a structure. The school board was impressed and so was the city council, for the walk was constructed later just as the elementary school children had proposed.

These are just a couple of case studies of students using problem-solving in the real world. Such examples are a bit dramatic, although they do not all have to be. For instance a class may observe problems in the immediate school environment--parking, lunch lines, locker rooms, or noise--and may begin to investigate these problems with the idea of creating alternatives to the existing situations.

Some Steps in Solving Problems

Problem-solving implies a certain freedom to explore the problem and to arrive at a possible solution. One tackles a problem to achieve objectives and not simply to use the process of inquiry per se.

The following steps are associated with the problem-solving technique:

1. Becoming aware of a situation or event that is labeled a "problem."
2. Identifying the problem in exact terms.
3. Defining all terms.
4. Establishing the limits of the problem.
5. Conducting a task analysis so that the problem may be subdivided into discrete elements for investigation.
6. Collecting data that are relevant to each task.
7. Evaluating the data for apparent biases or errors.
8. Synthesizing the data for meaningful relationships.
9. Making generalizations and suggesting alternatives to rectify the problem.
10. Publishing the results of the investigation.

Obviously, if you decide to use a problem-solving episode in your classes, you must realize that it will last for a period of days or even weeks. During that time, other learnings may be accomplished as well--for example, using of reference books, writing for unavailable information or data, learning how to interpret data, presenting progress reports to the class, and learning how to take responsibility for the conduct of a task.

If the problem allows for other independent study, that also may be arranged. The teacher may be able to conduct both the problem-solving episodes and the elements of the "regular" class lessons. In many cases, there are time lapses between phases of the problem-solving procedures. The teacher should make appropriate use of such time so that it will not be wasted.

The students will experience a sense of accomplishment in problem-solving. We suggest that the teacher plan for a systematic evaluation of the episode. You can adapt the evaluation forms presented in the treatment of discussions. In this manner, both the teacher and the learners will be able to benefit from the experience. Problem-solving, then, is one more inquiry technique that is available for making schooling a more memorable experience.

Discovery Learning

Who really discovered America? Leif Ericson seems to have been the first European to visit our shores. However, Christopher Columbus gets the credit for the discovery simply because he announced it first, while the territory is named for Amerigo Vespucci because he knew he had landed on a brand new continent and not in India. Thus the defining of discovery is difficult.*

Dictionary definitions of discover carry connotations that go beyond the denotations. For examples, examine the following definition quoted from Webster's New Collegiate Dictionary (1979):*

> **dis·cov·er** . . . 1 a: to make known or visible: EXPOSE b archais: DISPLAY 2: to obtain sight or knowledge of for the first time: FIND (~ the solution of a puzzle) ~ vi: to make a discovery-- . . .
> **syn** 1 see REVEAL
> 2 DISCOVER, ASCERTAIN, DETERMINE, UNEARTH, LEARN shared meaning element: to find out something not previously known to one
> 3 see INVENT

With all these connotations for one term, it is not surprising to observe so much confusion in the use of the word in the field of education. This is not to be construed as derogating the technique of discovery; it is merely meant to show the possibilities attending the state of the art.

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*We thank Kenneth A. Strike (1975) for the idea.

*By permission. From Webster's New Collegiate Dictionary c 1979 by G. & C. Merriam Co., Publishers of the Merriam-Webster Dictionaries.

The terms discovery learning and inductive methods are often used in place of the same generic term of inquiry. We shall differentiate among these so that each method will be better understood. Induction is a method of logic, while discovery is a method by which thoughts are synthesized to perceive something that an individual has not known before. In this vein, Kenneth A. Strike's (1975) comprehensive analysis of the logic associated with discovery learning may be of immediate use. Strike establishes two categories of discovery: absolute discovery and relative discovery. The former, absolute discovery, is that attributed to those classic firsts--the discovery of the DNA molecule's reproduction mechanism, America, new planets, theories, or synthetic materials. The latter, relative discovery, is used when an individual has learned or found out something for the first time.

Strike also presents four modes of discovery: (1) knowing that; (2) knowing how; (3) discovering that; and (4) discovering how. Finally, he provides a basic criterion that is essential for any act to be labeled a discovery. The discoverer must communicate both the what and the how to others. Thus, if you do discover the "Lost Dutchman Mine" in Arizona and do not tell a single individual, you have not made a discovery.

The four modes of discovery that Strike presents are very consistent with the thirteen major science processes that were described previously. Communicating is a major inquiry process and is very much a part of discovery. Also, the model that Strike describes implies that learners must "know" something before they can "discover" something. Content, knowledge, fact, and processes are all very much a part of the discovery strategy.

Although there is much luck involved in discovery, it must be remembered to quote from Louis Pasteur that "chance favors the prepared mind." Even though there is a trial-and-error element associated with discovery, the most important discoveries made by scientists are the result of careful observation and systematic research. Discovery makes use of the same processes and skills that were described for inductive inquiry and problem-solving. This should come as no surprise, since we have already emphasized the idea that inquiry, by its very epistemological nature, requires systematic conduct, not haphazard bungling. (Note: The method by which knowledge of a field is determined, as well as the limits and validity of that knowledge, constitute the science of epistemology. Inquiry-related techniques are based on the epistemology of empiricism. Observations, experiences, experiments, and replications are the techniques of empiricism--and of inquiry).

Examples of Discovery Learning

The Black Widow Spider - Judith Miles of Lexington, Massachusetts, wondered how spiders would spin webs under the effects of weightlessness. The subject of her curiosity was one of nineteen Skylab Student Projects conducted in the National Aeronautics and Space Administration (NASA) earth-orbiting space station in 1973. The Skylab Project placed three astronauts above the earth for 28 days. Judith's experiment demonstrated that a black widow spider was initially "confused" and did not spin the appropriate web pattern. But within a relatively short time, the spider did, in fact, spin the appropriate web!

Is this an example of problem-solving or discovery? We think that it fits in the category of absolute discovery because it was the first time that anyone had communicated the problem and had completed the research. Her science teacher, Mr. J. Michael Conley, had encouraged Judith to enter her idea in a contest sponsored by the National Science Teachers Association in conjunction with NASA. This demonstrates the partnership that develops when learners and teachers share in the excitement of inquiry.

Mystery Island - Not all discovery learning needs to be as dramatic as the NASA experiment. One technique that is commonly used to generate the fun and discipline accompanying the conduct of inquiry or discovery is to utilize the overhead projector and to present an event that requires student analysis. Jack Zevin (1969) reported on how to make use of a set of overlays that depict an unnamed island. The stimulus--the overhead projection--is presented in a group mode. The initial projectile shows the outline of an island. The map contains some standard clues to the island's general world location such as topographical symbols, rivers, and latitude and longitude symbols. This device is used primarily to focus the learner's attention on the event or to motivate inquiry.

The episode usually begins with the children being told that the island is uninhabited and that they are going to be the first persons to land on it. Their task is to choose where they will settle and to justify their choices. Ultimately the children are given other tasks such as to find the places that may be the best for farming, industries, railroads, harbors, airports, resorts, and the like. Inferences concerning rainfall, winds, deserts, and other natural phenomena can all be generalized by the students.

One can argue that mystery island is simply an inductive exercise. To be sure, induction is used; so is problem-solving and the application of previously learned skills and content. This stimulus does allow children to know "that" and "how" and to discover "that" and "how." The use of this device has unlimited opportunity for student inquiry.

Assumptions About Inquiry

Perhaps this topic should have been the very first in the chapter. However, if we gave the rules first, followed by the activities, we would be using a deductive approach rather than an inductive one. Recall that the method espoused by J. Richard Suchman is an inquiry technique based on deductive modes of logic. But it must be thoroughly understood that all inquiry exercises are predicated on selected assumptions about both learning and learners.

Several writers have addressed the assumptions about inquiry learning. The following list is a synthesis of collective views.

1. Inquiry requires that the learner develop the various processes associated with inquiry, which include those basic thirteen processes of science and those presented in this chapter.

2. Teachers and principals must be supportive of the concept of inquiry teaching and must learn how to adapt their own teaching and administrative styles to the concept.

3. Students at all ages and levels have a genuine interest in discovering something new or in providing solutions or alternatives to unsolved questions or problems.

4. The solutions, alternatives, or responses provided by the learners are not readily located in a textbook. Reference materials and textbooks are surely used during inquiry lessons, just as real scientists use books, articles, and references to conduct their work.

5. The content of inquiry is often process. In many instances, the product or solution will be relatively unimportant compared to the processes that were used to arrive at it.

6. All conclusions must be considered relative or tentative, but not final. Since inquiry depends mainly on empirical epistemology, the students must also learn that, as new data are discovered, conclusions tend to be modified.

7. Inquiry learning cannot be gauged by the clock. In the real world, when people think or create, it is not usually done in 50-minute increments.

8. The learners are responsible for planning, conducting, and evaluating their own efforts. It is essential that the teacher play a supportive role, but not the active role of doing the work.

9. Students have to be taught the processes associated with inquiry in a systematic manner. Every time that a "teachable moment" arrives while the class is being conducted, the teacher should immediately capitalize on it to further the building of inquiry processes.

10. The work of the teacher is usually increased owing to the many interactions that may emanate from inquiry teaching/learning.

11. Materials are nearly always needed for observation or manipulation.

This set of assumptions is presented so that you will understand better the theoretical bases on which inquiry rests. The more of these assumptions that your classes measure up to, the closer will your classes approach becoming learning laboratories in the truest sense of the term.

One last note, John I. Goodlad (1984) discussed the "flatness" of teachng in America's schools. Teachers tend to use only lecturing, testing, seat work, and recitations as the methods of instruction. We are making a plea for instructional "richness". Inquiry is the basis for understanding. Students not only know "what", but "why." And that is understanding.

In summary, our main intent has been to illustrate a general technique that has long been considered the exclusive domain of science teachers. We wish to clarify this false assumption; inquiry strategies, in fact, belong to all disciplines and to all grade levels. The only real limitation to the technique is the teacher's initiative.

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CHAPTER 7

CLASSROOM MANAGEMENT

Classroom management is a term which is often used interchangeably with classroom discipline. In reality, these terms are quite different. Classroom management emphasizes developing and maintaining a well-run classroom, whereas classroom discipline is a much narrower term which relates to dealing specifically with children's behaviors that are disruptive.

Some of the essential elements in establishing an effective system of classroom management include scheduling, classroom rules, storage and circulation of classroom papers and materials, and establishing classroom routines. While good classroom managers are inherently excellent teachers, excellent teachers will have well established patterns of classroom management.

Good classroom management requires a specific commitment made long before the students enter the classroom. It evolves out of a philosophy of being positive rather than negative. Primarily, it is helping a student adjust to the requirements of his or her school environment.

Clearly defined patterns of proper conduct endorse rather than hinder student-teacher and student-student relationships. Through working cooperatively towards mutually recognized goals, distractions and behavioral disturbances which would normally interfere with the optimum functioning of the student and classroom are kept to a minimum.

It is important that as a teacher you very carefully screen as many of the patterns of classroom management as you can determine and sort them into three categories: (1) those which you feel are imperative to maintain the type of classroom atmosphere which you would like and must be self-imposed, (2) those which you determine that there is some latitude but you would like to establish initially, and (3) those which you feel open and receptive to student feedback and decision-making.

Permissive teaching is not humanistic teaching. It is just plain disoranized teaching. It is difficult for a child to adjust to the requirements of the environment if he or she is not aware of the rules and procedures by which to direct personal behavior. Good classroom management emphasizes helping a child adjust rather than punishing a child for having not adjusted.

Therefore, insure that you have spent a sufficient period of time establishing patterns of appropriate behavior before the students enter the classroom. For many younger students, just having to analyze and respond in a group of 20-30 new peers is already a serious, traumatic experience much less having to, at the same time, try to determine the limits of acceptable behavior established by the classroom teacher.

The importance of having a well established classroom routine cannot be overly emphasized. In interviews with young adolescents who were asked, "How long does it take you to read a teacher?", the most common responses were "one period" and "2-3 days." When this is considered, the stark reality of what you do the first week of school establishes what you live with in terms of student behavior throughout the year becomes obvious: Nay - make it Day One!

The ultimate achievement of good discipline is self discipline on the part of the students. It is a classroom in which students assume acceptable behavior because that is the thing to do. In a well-managed classroom, disruptive behavior becomes a conscious effort on the part of the student. The classroom atmosphere is one in which acceptable behavior is the normal pattern and each pupil knows what the acceptable behavior patterns are at all times. Excellent classroom control is most often reflected by an absence of teacher behaviors directed towards maintaining classroom control.

What then are teaching behaviors which promote a positive classroom atmosphere? Consider the following suggestions.

1. Never allow students to make a decision unless you are willing to accept the decision they make. Trust quickly subsides if you renege on a decision made through student interaction. If you are not willing to accept a group decision, don't bring it up as a choice.

2. Punishment and reward is a poor approach. If we establish punishment and reward as our basic system of classroom management, we are creating an autocratic social system dominated by the presence of an omnipotent decision-maker who is the ultimate authority. With the structure of modern society, our power over children is sharply diminished. Children will generally only develop a greater power of resistance and defiance after punishment. With the greater realization of democracy as a way of life, and

recent legal decisions, we can expect children to make a conscious effort to assert "their rights."

Rewarding can be as bad psychologically as punishment. It is based on the same model, one in which there is an ultimate autocratic authority in the classroom. A reward-based program establishes a system of payoff for acceptable behavior and establishes a classroom atmosphere of "what's in it for me?" In a good system of classroom management, discipline is maintained by inner stimulation rather than by pressure in the form of punishment or reward. Try to establish a system of mutual respect, one in which a job is done because it needs doing.

3. Assume a disposition which is firm but not dictatorial. Children need limits and as the leader in the classroom, it is important that the teacher define these limits. There is a difference between domination and firmness. Domination implies impressing one's will upon the child, whereby, firmness refers to maintaining established roles which are consciously known by all of the individuals in the classroom, including the teacher. Remember, we teach more by what we do than what we say.

4. Maintain a humane classroom climate. Steve Duchi, (1979) defined a humane climate as having two goals: "(1) To provide through the school a wholesome, stimulating, and productive learning environment conducive to academic achievement and personal growth of youth at different levels of development, and (2) to provide a pleasant and satisfying school structure in which young people can live and work."

The crucial element in this regard is the teacher. Behaviors which are among the most important are amiability, open-mindedness, courtesy, being an active listener, and developing good self control.

In summary, classroom management is a process of teaching and limiting. It is a gradual process of imparting acceptable modes of behavior and instilling a sense of values which convey love, fairness, concern, and interest towards others and support for the ideas of a democratic society. Students need guided experiences and models, geared to their own age and level of maturity, in developing inner controls to develop self-operating limits. We have succeeded if we nurture students to a point where we have established trust, respect for each individual, and a capacity to control immediate desires to gain the rewards of longer term satisfactions and achievements. Effective classroom management is to plan carefully so that students have a clear awareness of the limits of acceptable behavior, and to live what you want to teach.

The above are one of the basic tenets for effective classroom management. Let us now focus on specific aspects of science class management.

Managing Materials and Children for Inquiry

It has been our personal experience in working with virtually hundreds of elementary school teachers and administrators that their greatest problem is the preparing, organizing, distributing, and collecting of materials needed for any activity-oriented science program. Even if the program that you use has a "kit," many tasks must be accomplished before it can be used by the students. Here are a few tested "tips of the profession" from teachers who have eliminated this anxiety.

Using the Class Members as Helpers

The critical element in materials management is to involve one student or a small group of students in every management activity. In one sense, this means making every science period similar to a birthday party, including the packages. The only difference between a party and science is that in your classroom, the packages will be those essential components from the science kit or, if you do not have an organized kit, the materials from the science center. (If you have no center, we will cover that problem, too.)

Recall from the previous work how you can easily establish small task groups. Well, you accomplish that exact task as an initial experience when beginning to teach science. Identify several groups of four. Allow each group to select a group name--Vikings, Seahawks, Gophers, Stars--and then place each team name on a small wheel. Along the outside of a larger wheel write a series of activities that must be accomplished. Then each time you teach science, move the wheel one "notch" so that all students participate in the materials management aspects of the science program. Figure 7-1 illustrates such a device. (Again, note that is a precursor for smal group or cooperative learning.)

But, back to the first science lesson, assuming that a kit is in use. Assign some seat work to the class and then gather your first group together to open the boxes in which the science materials are packed.

We have watched students from 5 to 14 years of age become very emotionally involved in this activity as every package is a mystery.

You give some general directions, such as "Joan and Suzie, take the big box down to the custodian for storage." In this manner, the packing crate or box is disposed of in a proper manner. Then give the remainder of the students specific instructions on how to inventory the items. You will find that each kit comes with some type of inventory checklist. By checking what is available immediately upon unpacking, you will know what materials need to be requisitioned from the office or delivered from the school district's central storage facility.

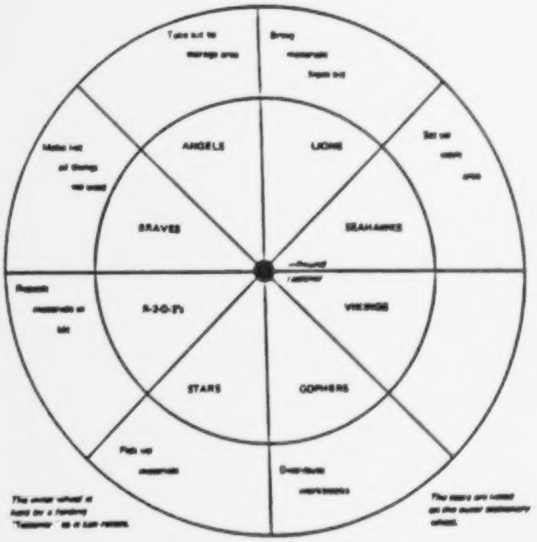
Take out to storage area
Bring materials from kit
Make list of things we need
Set up work area
ANGELS
LIONS
BRAVES
SEAHAWKS
R-2-D-2's
VIKINGS
STARS
GOPHERS
Repack materials in kit
Pick up materials
Distribute worksheets

Figure 7-1. Science Classroom Task Organizer

Make yourself familiar with the organization of the kit. If a "map" of the kit is neither included in the kit nor available through your central office curriculum staff or science consultant, have your students draw one for your use. The map should identify the trays and drawers, as well as the contents of each.

If your science program does not have a kit, then you and your students must become "explorers" in order to assemble the necessary equipment and supplies. The easiest way to handle the problem is to refer to the teacher's or student's guide. Make a list of the needed materials or equipment, locate them, give the list to a small group of students, and send them off to the storeroom or to wherever such materials are kept.

One way that you can collect materials beyond what must be provided by the school district to implement the science program is to send home a "scavenger hunt" announcement. List all the inexpensive items of equipment or supplies that people tend to have around their house or apartment. Again, the class will be the key to the success of the scavenger hunt. Schools that sponsor scavenger hunts often receive more materials than they can possibly use and can then share their good fortune with schools needing similar items.

When the materials have been gathered for the lesson, you must then develop a system that the students can use to organize the materials. Use shoe boxes, or any similarly sized boxes, for storage. Have teams of students label each box as to its contents and, most importantly, the concept it is being used to teach. Also identify the text or program used, the related page numbers, or the activity for future reference. If you have access to old editions or discarded books, tear out the pages neatly and staple into sets and include them in the box. In your teacher's edition of the science program write down what materials you have, where they are stored, the quantities you have of each item, and the success you had with the activity. The latter information will prove helpful the next year that you teach the activity.

Of course, the students compile the inventories for the boxes. This little task teaches responsibility, a most important facet of life. It is important to identify any materials that have been expended and need to be reordered. What are some easy ways of doing that? A simple way of maintaining a continuous inventory is to have the students identify all the parts of each kit on library cards. Color one side of each card red. Glue a library card pocket on the kit. When anyone has used the kit, the red side of the card is placed outward in the pocket to alert the next person that the kit has been used. Of course, this does not help to keep the kit replenished, but this system does alert the next student to check the kit before using it.

The above idea can be extended by placing two differently colored cards in two card pockets on the kit. In one pocket place an inventory list, the date when it was last checked, and the name of the person who checked it. This list would include all permanent items--e.g., thermometers, containers, and balances. On the second card placed in a separate pocket list the expendable items--spirit masters, handouts, charts, cotton, alcohol, and seeds. When some item is used, immediately order a replacement, noting on the card when it was ordered. Try to keep the science kits restocked at all times. It takes very little time after an activity is completed to inventory, restock, or reorder, but it means that when you want to teach science, you will not be thwarted because the materials are not in place or have not been replaced.

There are probably other methods that you have used or have seen used by your colleagues. Incorporate these ideas into your materials management systems. The anxiety of not having the materials when you want them can be totally eliminated if there is coordination among the staff members of a school and if the students are given responsibility for specific tasks. Or, ask the students to solve the perceived problem through a problem-solving session.

Preparing for a Science Lesson

Another major cause of teacher distress is the extra preparation for science classes. Actually, preparing to teach a lesson is simply one of the "occupational hazards" of the profession. Every *effective* teacher prepares for each lesson in every subject or discipline. For the elementary school teacher this may mean from 8 to 10 different preparations each day. The number may vary among individuals, but the magnitude is there; each planning and preparing step must be carefully accomplished so that your time is used most efficiently.

To conduct a science lesson you will, of course, have to read the teacher's manual and the student guide to understand the learning objectives and the activities to be utilized. You do that with most of your lessons initially, so nothing new is added to your workday.

Now, here is a useful tip. Why don't you and one or two of your colleagues get together for lunch and chat about the science program? Why don't you suggest that they form a "science teaching cooperative" for the purpose of helping each other with the science lessons? Such an endeavor works best where there are two or more teachers assigned to teach the same grade level in the same building. If this is not the case, then coordinate with the teacher of the next grade to form a two-grade-level science co-op. If your classrooms have "open space" designs, this type of co-op will be easy to implement.

The basic idea is to learn and teach only half of the total science program. If your co-op is multigrade level, then you will have to learn a second component. You and your partner(s) will have to make the decision. If you make the decision to team, then each of you takes responsibility to instruct alternating science lessons. With one person acting as the "teacher," while the other acts as the "assistant," you double the available adult help.

Whether you teach science alone or as part of a team, the following suggestions apply. Since most science programs provide a teacher's guide, speed read it as the first step in the overall process of lesson preparation. And because most of you use planbooks of some type, we suggest that you coordinate the planbook, teacher's guide, student activities, lesson objectives, and evaluation procedures into one total instructional plan. Make notes in the margins of these various items. Keep notes on what works well and what tends to fail. "Debrief" each lesson with just a sentence or two on how you felt the activity went. As you conduct the science program, you will be creating a well-documented file on how to do it better the next year. Keep all your notes and continue to refer to them in the future.

At the same time that you clarify management acts, course goals, and specific learning objectives, you must also identify the student entry levels. What they have already learned, the degree to which they have retained this learning, their motivations, their apparent abilities, and their social and cultural backgrounds are all important data. By knowing several bits of information about your class, you can easily begin to accommodate students with handicaps or learning difficulties in your classroom. When you are aware of special student needs, you can more effectively adapt the physical or instructional environment to parallel unique learner needs.

If you are using a sequential science program, then you will have a general idea of what learnings have preceded your instruction and what will follow. However, it is the students who learn, not the scope and sequence charts, so you must seek information about the kinds of problems that your students might encounter with the present science lesson. Recall those 13 major scientific processes that were discussed. Many of them are related to learning processes in mathematics, language arts, social studies, and reading. By observing your students during those lessons, you will be able to make some predictions about the ease or difficulty that each one might have with the currently assigned science lesson.

It is critical that you know the relative reading difficulties of the science materials and the general level of reading achievement of the class members. If a small group of your students is below "grade level" in reading, you may have to establish some tutorial groups. Another alternative is to request from the science consultant materials that these children can comprehend. A third technique is to have a good reader prepare audio cassettes so that the poorer readers can listen to and thereby follow the written assignments.

The majority of activity-oriented science programs have rather limited amounts of reading matter. Such programs tend to require each student to synthesize or apply the various cognitive skills that are constantly being built or reinforced in the total school program. It is doubtful that they will have severe reading problems with activity-oriented science programs.

However, you will encounter the problem of students who have difficulty expressing their observations, computing their findings accurately, or preparing tables or figures that display their findings from a selected activity. Again, here is an opportunity to reinforce other skills by using the concrete aspects of the activity-oriented science program. Establish small groups, so that each group must report its general findings to the class, but only after each group member has had the opportunity to present his or her finds to the small group. Think of all the practice in self-expression that the students get in this manner. Rather than the usual question-and-recitation period, the science period becomes one of high personal involvement with a great deal of interaction.

Some of the above tips might not be totally classified as "pure planning." Yet, it is by planning and making contingency plans that the best teachers carry to fruition their instructional goals and objectives.

Other Coping Skills

Once the general plans have been prepared, you learn to cope with the reality that you truly do not know all the possible responses to all the possible questions that will be asked. Again, this is one of the "givens" of an activity-oriented science program. Actually, it is a given in science per se. One of the authors had the fortunate opportunity to work with a group of elementary school teachers through an in-service project which, among other activities, included presentations by university research professors. Each professor gave a general presentation about the kinds of research activities in which she or he was engaged. In 10 separate instances, the elementary school teachers asked these highly published and, in several cases, "world-class" researchers questions to which each and every one politely responded, "I don't know," or, "That would make a great research problem," or, "I'd never thought about that."

Of course, the classic response to your students ought to be, "How can we find out?" "Is that a testable question?" You need not burden yourself with the responsibility to know everything there is to know about science. Shift some of that burden to the class members. If any one of them has the interest, you can bet that there will be an oral or written report to the class that addresses the problem. If no one follows up on the problem or the question, then you need not worry either, for that is just what happens in the real world of science: There are questions that go unanswered because they are beyond our current knowledge base or they are too trivial on which to expend one's energy.

One activity that you might consider establishing is a list of ~Unanswered Questions" on the bulletin board. Every time someone asks a question that is "unanswered," it is placed on the list by the asker.

In this fashion nobody loses face; everyone is a winner. As time passes, however, there will be students who will discover a possible response to some of these questions. They can then pull out the question and post it with the response on a bulletin board.

Another coping skill is to establish a file of recurring problems or questions that tend to be raised each year. Begin that file in your lesson planbook, and add to it after each science lesson, if necessary. At the end of the year or semester, prepare a short recapitulation of the specific problems. Then you can seek the responses from the district's science consultant--if you have one--or from other professionals.

One major coping skill that needs to be sharpened when teaching activity-oriented science is the ability to accept divergent student responses to either questions or interpretations of data. You must expect that in many science lessons, there will be a multiplicity of responses and even some creative ones. One goal of real science is to allow and encourage novel solutions and creative responses.

You must also remember your professional obligation to accept novel student responses. You are not placing any value on the question or the response. You are simply accepting the prerogative of the student to be novel or creative. You may not use subtle "put-down" tactics, regardless of how seemingly outlandish a student's point of view may be or how opposite it is from your expectations. By allowing, nay encouraging, diverse responses, every member of your class can become a star for a moment. That tiny accomplishment can be a significant event in the school life of every student.

Several of the above topics may not seem directly related to preparing for science teaching. Yet, keep in mind that you must now be sharpening some special skills that are emphasized when teaching science because inquiry is the essence of science. The above ideas follow a logical extension of that essence. In science, one prepares to be just a bit more novel. Or, maybe, it is simply that you will be using many of the skills and techniques that were taught in science courses, but that went without notice. Too, the above methods were probably discussed in teacher preparation classes, but at the time, they may not have seemed relevant to the real world. Whatever the case, teaching science is just that--teaching. With teaching comes the need to understand and implement useable and successful classroom management strategies.

Incorporating Science Learning Centers

One major problem continually confronting elementary classroom teachers is to find time to teach activity-oriented science programs appropriately. One solution is to incorporate science learning centers into the school science program. Note: If your school does not have any district adopted science curriculum, then you can easily establish a developmental or hierarchical sequence of science topics and design a series of science learning centers as the delivery system (Orlich et al.).

Getting Started

When first thinking about learning centers, you might ask yourself "Why a learning center?" The authors experienced the same question, but after they implemented the center concept, the question became, "Why did we wait so long?"

Learning centers allow you, the teacher, to use a multilevel approach to curriculum design which more closely matches the level of the children. In science, interactions are encouraged between peers. Centers allow children to work and conduct activities and to tutor each other. Further, science has a goal of helping young people become conscious of choices and decision-making. Centers can assist students by providing experiences in making choices; setting individual limits; and planning and attaining individually prescribed goals. Learning takes place through various styles. Manipulative activities and written assignments can all be a part of any center. As a teacher, you too, make learning-oriented decisions.

Objectives

Learning centers are usually developed to individualize science instruction. By developing science learning centers that allow for some self-direction, more time is generated to meet the individual needs of other students. This point will be developed further under "Management."

Science learning centers function most effectively as extensions of the basic science concepts of the school's curriculum. They are NOT substitutes for science units. Rather, the learning centers provide instruction of basic science skills, remedial help, and immediate reinforcement of language arts skills.

Most science programs incorporate inquiry, and use both inductive and deductive reasoning. Science learning centers can be constructed to follow those strategies and also to provide some individual creativity by establishing "challenges" where children apply the newly learned concepts.

Designing a Science Learning Center

Most teachers have file drawers and boxes of dittoes, books, materials, equipment and sometimes "junk." These "priceless collections" all help to build science learning centers. For example, sort through files, boxes, teacher guides, books, and magazines, to gather as many ideas from them that relate to your particular grade levels for the science curriculum.

"Brainstorm" for ideas that can be easily adopted and incorporated into your program. We realize that many ideas could be generated from local resources, e.g., department stores, displays, books, pictures, stickers. These all served to stimulate our minds further. For example, if a unit were being done on space, space-related materials could be examined.

Teachable Moments

Learning centers are very applicable to teachable moments--those moments which present themselves during an actual lesson; especially when a child raises a question about a different topic. If you're discussing a unit on compasses or directional finding in preparation for outdoor camp, and a child asks, "How does the magnet work?" you have a wonderful opportunity to branch out and investigate magnets and their properties. You may or may not choose to do an entire unit on magnets, but _if_ many students are interested, then you simply construct a science learning center on magnets and develop appropriate science activities.

Unteachable Moments

These are the moments most of us have experienced in our teaching when minutes seem like hours. Students are not attentive and you are not exactly inspired yourself. Why? Because the work from one science textbook is complete or you are involved in discussions, or you follow-up on another activity or your usual routine becomes unchallenging. Even the most experienced or creative teacher has trouble providing enthusiastic responses for such moments. Science learning centers provide invaluable assistance for those great unteachable moments by allowing an extension of the science concepts that are being taught.

Our rationale is contingent on having a correlated science program and set of science learning center activities. The learning center is just that--for learning. Students begin to appreciate content especially when they have an opportunity to apply their newly learned science skills.

Constructing A Science Learning Center

Construction of a science learning center is easy when you have all your ideas "in mind" or on "scratch paper". Prepare "precut" cardboard and colored tag board in advance of the actual construction time. This may involve one or more adults to speed the production. Cardboard can be found anywhere--grocery or appliance boxes are excellent. Using a large paper cutter, cut the board to desired size. After many "trial and error" centers, we suggest that your centers stay within an 18-inch square size (smaller seems AOK, but not larger). Our size criterion is determined by the fact that clear contact paper comes in 18-inch widths.

We have found that "tri-fold" centers are the easiest to construct and store. To construct a "tri-fold" you need three pieces of cardboard (all the same size), three pieces of colored tag (the same size as the cardboard), duct tape, rubber cement, and clear contact paper or laminate film. Lay the three cardboard pieces next to each other leaving about one-quarter inch separation (see Figure 2). Place the duct tape sticky side up on a table surface, then lay the cardboard onto the tape. Leaving a one-quarter inch gap between boards allows the center to fold for easy storage.

The next step is to place all needed information on the colored tagboard. This includes the title, directions, examples, factual information, and activities to be done. We have found that plastic adhesive letters for titles and such, save a great deal of construction time. Be sure to do any lettering of directions with permanent felt markers so you may reuse the center.

When all this is on the tagboard "spice it up" with cartoons, or whatever. Cover the three separate pieces of colored tag with either clear contact paper or laminate material. Do this before you adhere the tagboard to the cardboard. When all working surfaces are covered with contact, use rubber cement to glue the colored tag to the cardboard. Be sure to cover with contact any cards that will appear in center pockets and also pieces that might belong to a game that will be housed with the center. Children will not intentionally destroy these cards, but continual use causes deterioration if they are not covered. Construct and use one center and enjoy it for many years to follow!

Again. . . materials needed are:

1. An IDEA!
2. Three pieces of cardboard
3. Three pieces of colored tag (same size as cardboard)
4. Duct tape
5. Stickers or decorations
6. Clear contact paper or laminate
7. Rubber cement

Remember these quick steps:

1. Cut cardboard and colored tagboard the same size
2. Use duct tape over the edges of cardboard
3. Place information on colored tag
4. Add any colorful decorations to colored tag
5. Cover colored tag with clear contact or

laminate

6. Glue colored tag to cardboard with rubber cement

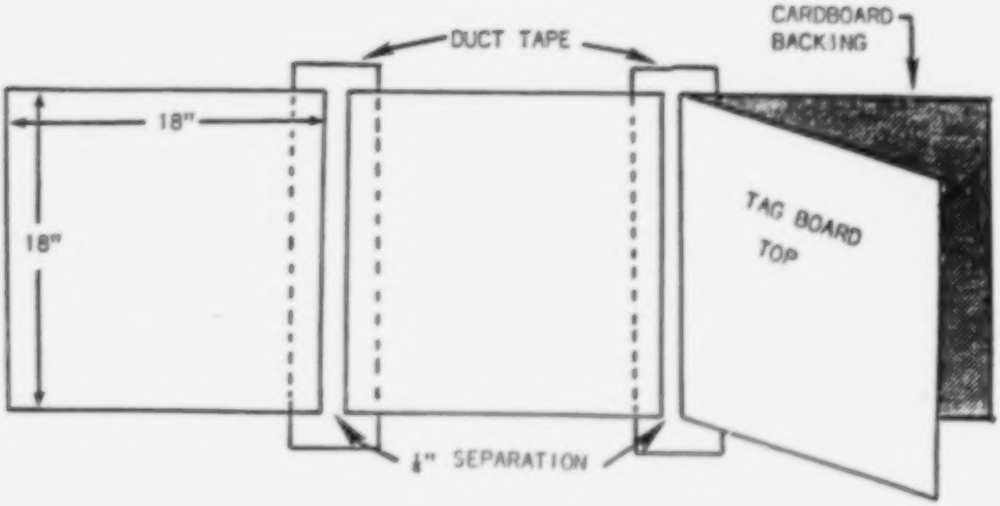
DUCT TAPE
CARDBOARD BACKING
18"
18"
TAG BOARD TOP
¼" SEPARATION

Figure 7-2. General Construction of Three-fold Science Learning Center

Managing Learning Centers

In managing science learning centers, two major systems seem to be most prevalent. One is to use centers only during student "free-time." However, many students don't ever seem to have free-time. Therefore, we suggest the management scheme illustrated in Figures 7-3 and 7-4.

Lab Groups #1	#2	#3
Teacher Seminar	Follow-up	Center
Center	Teacher Seminar	Follow-up
Follow-up	Center	Teacher Seminar

Figure 7-3. Management Grid

Center #	Group Number #1	#2	#3
1	Mary	John	Lee
2	Jo	Cassandra	Jerry
3	Leann	Billy	Steve
4	Sue	James	Rosalie
5	Larry	Kim	Jeff
6	*	*	*
7	*	*	*

Figure 7-4. Group Grid

Figure 7-3 shows the class being divided into three lab groups. Each group may wish to label their group with a science name. If so, place that name on your chart in lieu of Lab Group #1. The three sections on the chart represent the rotation on days you schedule science. "Teacher seminar" is where the group meets with the teacher for specific purposes such as demonstrations, discussions, recitations, one-on-one help, quizzes, and evaluations. "Center" is scheduling the lab group with the actual teacher-made materials that reinforce the seminars. These centers include audio tapes, games, manipulative devices, task cards, experiments or further readings. The "follow-up" is done at the students' desks, and includes written activities, research activities, experiment write-ups, all relating to science and the learning center theme.

Figure 7-3 can be used two ways in your room. Either rotate the chart for one day's science activities, or use the chart on three-day rotations. On day one, a lab group has teacher seminar; on day two, they do science centers; and on day three they are involved in follow-up activities. Such a method insures systematic development of the science concepts.

Figure 7-4 is posted in the classroom so that each child is self-directed to the correct center without disrupting others in the room. The students' names are a permanent fixture on the chart. The station numbers change daily. Each day the teacher moves all the numbers down and the bottom number moves to the top. These numbers coincide with the science learning centers in the room. You need to have as many centers in the room as you have students in each lab group. When first using learning centers, place two or three children at one center and rotate others through it.

Learning centers can be created just for "fun." However, their real advantage comes from the flexibility that they give the very busy elementary teacher. To be effective, science must have continued emphasis and activities in the school. Science needs an activity orientation to help children develop a "real" contact with the sport, as it were. By combining science learning centers with the actual science program, you'll have an enjoyable and fruitful experience and so will the children.

Safety as a Management Concern

Chapter 9 will dicuss safety in great detail. But it is such an important topic that we have divided the topic into two parts. Presented here will be those "nuts-n-bolts" aspects of science safety because the selected topics are rightfully classroom management issues.

Materials Management

Activity-oriented science requires the use of simple pieces of equipment. For the most part the items per se are no concern for safety. Yet, some flammable materials such as alcohol are common. If used, the bottles should be secured in a locked cabinet and clearly labeled. If a flame is required it is best to use candles securely anchored in a holder having sand in the base of it. Matches are needed to light candles and they should be kept in a secure drawer.

If hand tools are needed, all students should be trained in their safe use. Tools should always be placed back into their kit when not in use.

Electric appliances should be checked before use to be sure that the plugs are intact and that no wires are exposed. If hot water is needed, it might be safer to use an automatic coffeepot.

If blindfolds are to be used, have each child bring one from home. This reduces any possible transmission of eye or skin diseases.

Chemicals

In an elementary science program only weak chemical reagents should be used. All acids and bases should be dilute, and never in concentrated form. Acids, bases, and other solutions should be stored in separate areas. Label every chemical. If you inherit a classroom that has some older looking bottles of chemicals, or unlabeled ones, write the principal, requesting to have them disposed properly by the school district safety officer. Never dump toxic or unknown chemicals down the sink. Call the school safety officer.

While the list below is not inclusive, the chemicals mentioned should never be found in an elementary classroom.

1. Mercury or Mercury Compounds
2. Metallic sodium
3. Sodium or Potassium Hydroxide
4. Carbon tetrchloride
5. Formaldehyde
6. Pesticides

The above are dangerous and highly toxic. There is no need for them in elementary science.

Life Science Consideration

The life sciences play an important role in elementary schools. All aquaria or terraria should be inspected for cracks, chips, or breaks. Such items should be repaired or discarded.

All life science materials should be handled in an appropriate manner. Tiny plants, mold and the like should be studied in closed vials. If microscopic examination is done, then, students should be taught how to mount the materials on slides. After working with living things, students should wash their hands.

Standards are established for living small animals. Teachers should follow those guidelines. Any live insect or animal that can sting or bite children should not be used in the classroom.

Science should be challenging and fun. The subject does have some potential dangers. However, by planning for appropriate use of science materials nearly all potential hazards can be eliminated. Care of equipment and its reponsible use can be stressed so that all children are safety conscious.

Conclusion

Classroom management is really being well organized and ready to teach every day. Many management problems relate to safety, but we will cover that topic later in detail. The essence of management is to build student self-discipline and cooperation. The pay-off is in better science learning.

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CHAPTER 8

SIMULATIONS AND GAMES IN SCIENCE TEACHING

While inquiry has been stressed as a viable instructional method for at least most of the twentieth century, simulation--an adaptation or application of inquiry--is relatively new to the educational scene. Simulation--or gaming, as it is often called--has been used for entertainment for decades in the private sector. For example, the world famous game of Monopoly is one such simulation that is used for "enjoyment" by innumerable people.

But why do educators find games to be of instructional value? There are many reasons. Games and simulations are very useful to the classroom teacher because they can be used as application devices for the expression of previously learned principles, concepts, or facts. In other words, simulations have a definite place in the instructional spectrum as a planned learning episode. As a teacher, you make decisions about what children will learn in school. If your objectives lend themselves to the use of simulations, then you can add one more tested technique to your already full "bag of professional skills."

Brief Background About Simulation?

Simulation is the presenting of an artificial problem, event, situation, or object that duplicates reality, but removes the possibility of injury or risk to the individuals involved in the activity. Simulation provides a model of what exists or might exist in a set of complex physical or social interactions. Simulation is a representation of a manageable real event in which the learner is an active participant engaged in learning a behavior or in applying previously acquired skills or knowledge.

Clark Abt (1966), long associated with the preparation of simulation materials for the private sector, divides simulation into its three major components: (1) models; (2) exercises; and (3) instruction.

Typically, models tend to be inactive--that is, they do not interact with the participants. They remain static but do resemble some dimension of reality. Globes of the world, physical models of the solar system, and some case studies are examples of the inactive simulation model. However, computer-controlled models that provide active patterns of interaction with the users are now being used at various instructional levels. These models are just now becoming available to the public schools, as their costs are now within the schools' budgetary limits. In the not-too-distant future, these models may be commonplace in most schools. Models need not always be physical replicas of the real objects. Pictures, drawings, sketches, and maps can all be classified as models of inactive simulation.

Exercises are activities designed to allow the learner to interact with someone in either a physical or a social manner. Coaches have long utilized exercises as they plan for an upcoming game with the next opponent. Trade and industrial teachers, in setting up equipment that needs to be adjusted or checked (trouble shooting), allow the learners to interact with machines. Models of the solar system or the moon have been very common in science classes. As a simulation, a model helps provide a concrete object to help children learn science concepts.

Instructional simulations involve the learner in various functions. Paul A. Twelker (1968), a designer and early advocate of instructional simulations, suggests that instructional simulations can perform three functions. They can: (1) provide information to the children; (2) create situations in which the learner demonstrates some skill or knowledge, since the simulation elicits a response; and (3) assess the performance of the participant by measuring it against an already established standard.

While simulations have long been used in the military, in business, in medicine, and in administrative planning units, their introduction into the schools is a more recent event. However, the latter part of this statement should be qualified, as teachers have for years used play stores and school councils, as well as other interaction methodologies, (the fire drill) as instructional devices to reflect selected dimensions of reality.

Purposes of Simulations

There appear to be at least ten general purposes for the use of simulations and games in education. The following synthesis provides a checklist of purposes. Simulations or educational games are designed to:

1. Develop changes in attitudes.
2. Change specific behaviors.
3. Prepare participants to assume new roles in the future.

4. Help individuals to understand their current roles.

5. Increase the student's ability to apply principles.

6. Reduce complex problems or situations to manageable elements.

7. Illustrate roles that may affect one's life but that one may never assume.

8. Motivate learners.

9. Develop analytical processes.

10. Sensitize individuals to another person's life role.

Each of these ten purposes, we must warn, cannot be obtained from any one simulation device. You select simulations or games that are appropriate for a specific science learning objective. One of the desired developments that result from simulation is that the learners will be stimulated to learn additionally from the exercise by demonstrating independent study or research. Furthermore, as students engage in relevant simulation exercises, they may begin to perceive that knowledge learned in one context can become valuable in different situations.

This is, of course, the well-known concept of "transfer" that keeps psychologists so perplexed.

In our own use of simulations, we have observed that students become immersed in the activities almost immediately. Games and simulations are great "icebreakers" for diverse groups of students. There is also an element of risk-taking for all players. Even though there is no penalty for the participants, each individual tends to view the simulation from a serious, personal perspective. We made this observation, especially in case studies that required the participants to make simulated decisions concerning the espousal of critical human values. In the "bomb shelter" simulation (in which you are under nuclear attack and can only allow five persons in your shelter and must decide who gets in), we observed students who refused to participate because this value decision went too much against their own moral commitments. Of course, we do not suggest that all simulations involve such personal intensity. We cite this example merely to demonstrate the intense personal involvement that can occur with simulations.

Types of Simulations

Robert Maidment and Russell H. Bronstein (1973) identified three major types of simulations: (1) human simulation, which includes role playing; (2) person-to-computer simulation, which is slowly increasing in use; and (3) computer-to-computer simulation, which is the most sophisticated and complicated type and is currently used to generate global or whole earth models. The third type of simulation may be used by your students when they enter the professional world as researchers or business leaders.

Educational games currently available to the schools tend to use two basic patterns, as Alice Kaplan Gordon (1972) reported. The first is the game board, which resembles commercially prepared games such as the classic Monopoly. In the elementary school game of "Neighborhood," students develop a geographical area, shown as a grid on a board, by placing tokens that represent people, factories, stores, and the like on the grid. The objective of the game is to learn how complex interactions take place in neighborhood development. As the game progresses, the board becomes filled and the players must accommodate their communities as best they can. By the end of the game, the players observe the final course of the development as graphically portrayed on the board.

The second format identified by Gordon is the role-play game. The roles of such formats are designed to teach selected social processes--for example, human relations, negotiations, bargaining, compromise, and sensitivity. These simulations usually have a scenario and character profiles so that the conditions, persons, and consequences of all collective actions may be charted. This format is used to a great extent in a curriculum developed by the National Science Teachers Association for Program of Energy Enriched Curriculum (PEEC). A series of simulations are provided so that children apply a wide range of energy and ecologically related concepts. In most of these games, decision-making and planning are two processes that are reinforced.

Regardless of the format, all simulations and games have rules that establish their objectives, the types of roles that the players are to assume, and the types of actions that are allowed or disallowed.

Is there a difference between a game and a simulation? One distinction is that games are played to win, while simulations need not have a winner. In some simulations, it is difficult to determine whether or not there are winners and losers, and which players belong to which category. For example, in a simulation of a legislature, the issue is whether or not to raise taxes. Students are provided with character profiles and a scenario describing the various conditions of the issue. After the arguments are made, a vote is taken. In this simulation, it is difficult to say who has won.

Simulations seem to be more easily applied to the study of issues rather than of processes. The principal purpose of a simulation is to encourage students to express, in their own words, the basic arguments for the various sides of an issue. Games, however, try to get students to make more intelligent decisions as they learn the processes represented in the game. Obviously, the distinctions are not clearcut. Purists may find that any labeling of these activities may be a matter of semantics.

A classification scheme prepared by Katherine Chapman et al. (1974) expands Gordon's two main simulation formats. They determined that educational simulations and games have five main characteristic activities:

1. Role-play.
2. Simulation exercise.
3. Simulation-game emphasizing role-playing.
4. Simulation-game emphasizing strategy.
5. Game.

Each type of activity is classified according to five additional characteristics. The first describes the probable learning outcome (the predominant problem orientation) of the activity. The four others are structural traits: primary role definition, group size, complexity of activity, and problem-solving mode.

Complexity of Activity

The complexity of an activity is determined by the amount of information generated by the activity. Role-play tends to have one main activity. It has a narrowly defined focus and deals with immediate issues and consequences. Little or no chance enters into role-play. In fact, it is not very complex. Simulation exercises, simulation-games, and games, on the other hand, often involve long-term planning and complex analyses. In these activities, which tend to be more realistic, children pursue different goals by various means, and time is often simulated. In some simulation activities, chance plays no part, while in games, the outcome is usually based entirely on chance.

An example of a game that requires student interaction and cooperation is the "ZIP Code Game" (Orlich, 1986). The objective of the game is process building, i.e., to determine the geographic patterns associated with the U.S. Postal Service ZIP Code System. Materials include an outline map of the USA, cards with state capitols and their ZIP Codes listed. Teams of students begin to draw cards and then locate the state capitol on the map and list that ZIP. It becomes apparent that several capitols in specific geographic areas must be known before any meaningful pattern appears.

When the children determine a pattern for a specific geographic area they are asked to predict the possible ZIP Codes of states yet to be identified in that area. The predictions must be based on evidence. Students give their ZIP predictions and tell what evidence they used to come to their conclusions. Again, this game is excellent to use when one adopts the cooperative learning model. Team members must show information in order for the team to work out the pattern. Further, the game allows students to make a series of generalizations about the ZIP system, all of which can be tested with data.

The problem-solving mode seems to be partially characterized by the amount of information shared by the players. When there is little information about other players' strategies, extreme competition and lack of trust often result. This is typical of pure games, in which players from the start see one another as having opposing interests. When more information is shared, players begin to perceive common interests and are more likely to build alliances and trusting relationships.

The amount of information-sharing that occurs depends on the amount and style of negotiation allowed. There appear to be two kinds of negotiation styles. The first is formal-rule behavior, in which players talk to each other because the rules dictate it. The second is informal-rule behavior, in which responses to problems are neither forbidden nor required by the rules. While formal-rule behavior usually results in bargaining activity, informal-rule behavior may lead to cooperation through shared interests.

Another element in the problem-solving mode is goal orientation. If winning is a goal, then the efforts to win tend to be more intense. In noncompetitive activities, such as role-playing and many simulation games, cooperation tends to develop because the objectives are more open-ended.

We do not wish to confuse you with concepts, terms, and definitions. Our intent is to illustrate how simple or complex a simulation may be. Furthermore, there may be few distinctive characteristics by which to differentiate among models, exercises, or instruction in this model. Purists may prefer to make a clear distinction between simulations and games. We will try to blend the concept of "simulation" with "game" while illustrating how these two overlap with instruction.

"Science and the Common Place" (Orlich, 1988) shows how easily data may be found that require student problem solving. Technically, these activities might not be "pure type" simulations. But they do reflect a dimension of reality that provide problems to be solved. Weather data abound. In "Science and the Common Place" one observes how easily data can be assembled from newspapers and used as an inquiry or thought-provoking stimulus.

Selected Techniques

Role-Play

Role-playing is a discussion technique that tends to develop selected skills. Simulations that use role-playing are based on that discussion technique. Students are given specific roles for the purpose of acting according to some stereotyped behavior pattern. In a "free-wheeling" role situation, only the character types are given to the students, who will then extemporaneously act out the roles and behaviors.

In simulations using role-playing, there is usually some structure, a stated issue to be resolved, and in some cases a winner or loser. A role-play simulation may be structured to provide one-to-one interaction or may resemble a small-group interaction. For example, L. Gerald Buchan (1972) provided a series of role-playing episodes for educable mentally retarded children in the schools. He presents a specific problem on which the children must focus. In one episode, there are four children who act out academic and behavioral problems, while one child plays the role of teacher. Initially, the students are given "prompts" to set the stage for the episode. After conducting the role-playing experiences, the real teacher critiques the entire happening with the group of five children. This is done to develop more appropriate behaviors in the children.

We find Buchan's presentations about role-playing to be very timely, especially with the passage of PL94-142, the education for all act. Role-playing as a simulation technique for children with learning disabilities of any kind may help both anxious teachers and handicapped students to cope better with the children's problems. When this technique is used, an affective dimension is added to the program of studies.

Simulations

Simulation requires participants to be involved as active players, but they may or may not have fixed roles. An example is seen in the game of "Ecology" (1970), which may be played with two to four persons. The simulation makes use of a game board. The object of the game is to create a balance between human activities and the environment. The game is structured so that the players progress from an era when life was simple and food had to be hunted, to a more complex era when agriculture predominated, to an age when the world became industrialized, and finally to the present when the integrity of the environment is at stake. Wars, crises, tests, and some elements of change are included in this exercise. The cognitive learning outcomes that emerge are that: (1) land use is a complex issue; and (2) values and ethical concerns play a vital part in decision-making.

Simulations that emphasize role-playing tend to be oriented toward cognitive learning outcomes. Information is provided to all players and each player assumes a role in the simulation. The group is informed of the general situation. The members then interact with each other and with the materials, using the information that emerges as a result of all the interactions.

Joseph Abruscato (1986) provdes several examples of using classroom microcomputers in a science program. Collecting and illustrating data in tabular and graphic formats is one use. However, he illustrates a number of simulations that can be used. These include a model cockpit to simulate flying, a food chain problem, and problems associated with electric circuits.

Albruscato also discusses the use of a videodisc/microcomputer system. The video-disc provides film clips of various scientific or technological problems. The computer is programmed to display questions about the episode. Of course, classroom use of such a system is contingent on programs that augment a science program.

A teacher can integrate the computer system into the classroom, thus relating science to a technology that makes the science usable. One other dimension may be then added--the societal impact. In most simulations, decisions must be made that affect or impact social values. Science may be value free, but the applications are not. For example, pesticides do reduce insect damage. But pesticides also poison water, birds and other animals. The decision for appropriate use is a value judgement. Computer simulations can illustrate the impact of those decisions.

Using "Decision, Decisions," Barbara Vincent (1986) described how 21 sixth graders integrated a computer simulation into the science and social science program. The simulation used by Vincent was oriented to foreign policy decisions. Students observed how decisions have broad implications. According to the author, a transfer of decision-making skills to other academic and non-academic areas was observable.

Vincent did caution that simulations must have an educational goal to be most effectively used.

Richard B. Powers (1985-86) described use of "The Commons Game" that illustrates the dilemma of competitive and cooperative management of natural resources (whales). Through this game students learn that a competitive system of harvesting whales ultimately leads to their extinction. In this sense the simulation is an excellent follow-up to "Krill" which is a game about feeding habits and the food chain of whales.

Predator-prey concepts are illustrated with Michael L. Waugh's (1986) "Pasta Predation". In this game differently colored pasta are distributed in a grassy area. Students "prey" in a given time period. One charts the number of prey removed from the environment to determine if any one color is more preferred over other colors. This game is an adaptation of "Sticklers" in which colored toothpicks are distributed randomly over a lawn. In the case of "Sticklers," fewer green toothpicks are discovered by the "predators". Concepts associated with protective coloration, predator-prey relationships and selective predation are concretely reinforced by these games.

L. Kirkup (1986) described the use of a microcomputer in describing magnetic fields. The lines of magnetic strength can ultimately be calculated.

Similarly, Kenneth Fuller (1986) describes a "Hot Dog Stand" microcomputer program that helps young children plan and compute arithmetic problems in which outcomes depend on random events.

Charles C. Spraggins and Robert E. Rowsey (1986) developed simulations applicable to topics of geologic time tables, cells, and the circulatory system. Simulations were equally effective as using student work sheets.

Also using a computer protocol, Alan N. Rudnitsky and Charles R. Hunt (1986) attempted to determine how fifth and sixth graders solved cause and effect problems. In this simulation, the pressing of three selected computer keys caused a graphic cursor to move in specific directions. Students were expected to determine which key (cause) made the cursor change directions (effect). The authors concluded that those students with knowledge of LOGO developed more logical approaches to problem-solving.

Perhaps problem-solving strategies are reinforced more with computer simulations than with textbooks. For example, Robert L. McGinty (1986) had found that word problems in fifth grade math textbooks had decreased between 1924, 1944, and 1984. However, drill and practice problems increased. So, is it any wonder that pupils do not show a desired proficiency in problem-solving skills.

With greater numbers of mentally handicapped children being mainstreamed, teachers need to identify relevant simulations to aid these learners. Four different research studies all showed the efficacy of using simulations in the training of this special group. (See: Matheidesy, 1987; McDonnell & Horner, 1985; Plienis & Romancyzk, 1985; and Richman, 1986.) In each study, mentally retarded children learned to accomplish specific tasks by first simulating them.

Of course, we reiterate the rationale that games or simulations are selected to help achieve educational objectives. This technique is a means to an end, not an end, per se. By using appropriate simulations, a teacher allows the students to apply knowledge, develop decision-making skills, and learn to work cooperatively in a small group.

Conducting Games or Simulations

There are several procedures that have proved to be successful and should be noted as you decide on the role that games or simulations will play in your teaching styles.

The Teacher

The optimal way to learn about a selected game or simulation is to gather a group of teachers together and to play the game. This assures familiarity with the basic rules. In many cases, the teacher must prepare handouts, materials, and other objects. All pre-game arrangements can then be made in advance of the actual classroom use of the game.

In role-playing games or simulation, the teacher must be knowledgeable about roles, rules, and conflicts. Also, it may take from two to four traditional class periods to complete some of the more lengthy games or simulations. The teacher must be willing to devote that much time to the activity. Generally, one cannot appreciably reduce the time needed to complete a game or simulation.

The Class

Once the teacher is prepared, the class must be briefed on rules, roles, scenario, conditions, and options. This should be accomplished prior to conducting the exercise. Bear in mind that students learn the rules of the game not by reading about them but by practicing them. The roles can be assigned by drawing lots, or the teacher may give major roles to students who do not perform well in conventional classroom activities. If the teacher uses simulations regularly, the method of assigning student roles should be rotated.

Once the game is begun, the students usually require a "referee"--the teacher. Much adjudicating will be required with initial experiences. The teacher should clarify rules, interpret situations, or answer questions. The teacher should be careful in responding so that one player does not gain an advantage over another because of the teacher's maturity or experience.

During any simulation, there will be much activity and "meaningful noise." The principal and your colleagues in neighboring classrooms should be warned about the game ahead of time, so that they may plan accordingly. This is not to imply that your classroom will be in chaos but there will be more movement, activities, interactions, and more noise than usual.

During the course of a simulation or game, the teacher should constantly move about observing the roles of the players and perhaps even systematically noting various reactions so that a critique may be made when the game is finished. If possible, we suggest that some type of form be used for tabulating student behavior, such as those illustrated in our treatment of discussions. In some cases after your evaluation, you may decide to modify a selected game based on an initial experience of the class.

Designing Your Own Games

It is easy to design your own simulation or game. There are about ten steps involved. The general design rules, as presented by Alice Kaplan Gordon (1972), follow:*

1. Define design objectives.

2. Determine the scope of the game in terms of the issues to be examined, its setting in time, and its geographic area.

3. Identify key actors in the process, whether individuals, groups, organizations, or institutions.

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*From Alice Kaplan Gordon, Games for Growth (Palo Alto, Calif.: Science Research Associates, 1972), pp. 123-131. Used with written permission of Science Research Associates.

4. Define the objectives of the actors, in terms of wealth, power, influence, and other rewards.

5. Determine the actors' resources, including the game information each receives.

6. Determine the decision rules, or criteria, that actors use in deciding what actions to take.

7. Determine the interaction sequence among the actors.

8. Identify external constraints on the actions of the actors.

9. Decide the scoring rules or win criteria of the game.

10. Choose the form of presentation (board game, role-playing) and formulate a sequence of operations.

Other Considerations

Our brief introduction to the use of classroom games or simulations must surely have caused you to ask yourself the question: Will they work for my area? The answer depends on what your goals or objectives are. If you want to build processes associated with decision-making, then games and simulations provide alternatives to the usual classroom routines. If you wish to promote human interactions, then simulations and games are appropriate. If you intend to provide experiences that students may not have in the routine application of learning skills or principles, then you should use games or simulations that will achieve this end.

Some Research Findings on Simulations

The research on simulations is quite voluminous. Gerald R. Girod (1969) and Alice Kaplan Gordon (1972) provide both evidence and case studies that support the use of simulations to improve the cognitive and affective skills and attitudes of the players. Hubert J. Klausmeier and R.E. Ripple (1971) report that games, role-playing, and simulations are effective means of cultivating desirable school-related attitudes.

The review of games and simulations by F.L. Goodman (1973) regards such activities as excellent student motivators. Karen C. Cohen's (1970) work shows that a group of previously unmotivated and apparently disinterested truants were persuaded to attend school by enticing them with the "Consumer Game." We agree that the use of simulations and games does increase student interest in the subjects being studied.

James M. Migaki, a colleague at Washington State University, has long used his own creation, "The Pancake Game," as an end-of-semester activity for junior-year students in his methods class. The amount of interaction, interest, and application of skills and knowledge is tremendous. Students who interact very little during the regular class periods begin relating to each other as if they are old friends. Thus, if you wish to increase the interactions within your groups or classes, you should use a game that requires interpersonal contacts.

Games and simulations are devices that can help to establish a supportive environment that is conducive to learning. Teachers have reported that the use of simulations and games seems to help many "quiet" students to participate more in class activities. Jay Reese (1977) suggests that simulations may be good learning motivators. He adds that there is a need for a discussion or debriefing session at the culmination of any simulation activity. The debriefing helps the students to determine the implicit or explicit learning to be gained from the experience.

Analyzing the concept of simulations, Katherine Chapman et al. (1974) believes that simulations and educational games tend to promote logical reasoning and decision-making. In addition, these authors state that simulations provide a steady source of feedback to all participants. By learning how to use the feedback, the players learn how to process new knowledge and to modify previously made decisions. Such activities tend to provide a more complex learning environment than that usually found in the classroom. Thus, a major advantage of games and simulations is that they teach students how to establish a strategy and how to modify it through rational means.

Simulations also can be levelers of ability. Children who are judged to be poor students can participate on a near equal, if not totally equal, basis as the better students. More importantly, having a chance to compete or participate with others helps to build students' morale and makes the classroom a more enjoyable place in which to learn.

When does one integrate a simulation into the curriculum? Chapman et al. (1974) suggest that "folk wisdom" provides teachers with at least five possible instances when it would be appropriate:

1. After a unit or as the culminating or generalizing activity.

2. As rewards to students who complete assignments.

3. For a change of instructional pace.

4. To introduce a unit or to motivate students to learn.

5. To help meet the instructional learning objectives.

Simulations are excellent devices with which to develop understanding in business practices, politics, and environmental issues which may be controversial topics for the class. By inventing a simulation with which to examine the issues in question, the teacher provides the students with a safe place in which to reflect on their personal values and on those of society and how they interact, compete or compliment each other.

Simulations have been used by nearly every teacher who has included an "activity corner" in the classroom environment. In many cases, the games can be developed by teachers in cooperation with professional game designers. Some teachers purchase the games, while others recruit older students to create games by simply giving them the objectives, materials, and the basic plan. This challenges teachers who wish to stress creativity to use simulations, inquiry, and problem-solving.

Terry Armstrong and Michael Heikkinen (1977) suggest that the teacher offer an open-ended challenge to the class. Although they are discussing inquiry in general, their suggestion also applies to simulations, especially those involving educationally disadvantaged youth. The main advantage of an open-ended challenge is that it allows a whole spectrum of appropriate responses. This is one sure way of improving the self-images of young people who have not had much of a chance to be winners. As the teacher, you can reward or reinforce a wide variety of responses--the most original idea, the best technique, the neatest paper, the toughest project, or the greatest number of alternatives. There is no limit to the number of positive school-related rewards that can be given to students.

Locating Sources About Simulations

Although the distribution of simulations is rather widespread, we wish to suggest three excellent sources of simulations for your use. Robert E. Horn (1977), David W. Zuckerman and Robert E. Horn (1970), and Jean Belch (1974) provide references and information about simulations that are easy to use. They describe thousands of simulations so that you may make the most appropriate selection for your class and your learning objectives.

Robert E. Horn (1977), David W. Zuckerman and Robert E. Horn (1970) provide a list and brief descriptions of almost 1,000 simulations and games. Sixteen different descriptors are listed for each entry. These descriptors include information about: copyright, age level, number of players, playing time, supplementary materials, special equipment, preparation time, descriptions, roles, objectives, decisions, purposes, user report, editor's comments, costs, and producer. By referring to the works of these authors, you can quickly determine the status of published and unpublished simulations.

Jean Belch (1973) provides an eleven-point system of descriptors similar to those just listed. She also supplies valuable cross-referencing by subject, author, and producer. Additional sources of simulations are typically listed in books and articles on the topic.

Most activity-oriented science programs contain simulations that are easily incorporated in the science class. Included in the group are: Outdoor Biology Instructional Strategies (OBIS) and Science Activities for the Visually Impaired- Science Enrichment for

Learners with Physical Handicaps (SAVI-SELPH). Playing with energy is a book with energy related games, published by the National Science Teachers Association. Currently, there are several "Science/Technology/ Society" (STS) projects in which local curriculum materials are developed. Nearly all STS projects have simulations that require student decision-making.

We wish to stress one last point. Games, simulations, or inquiry devices should be incorporated into the ongoing instructional goals. These techniques are not entertainment mechanisms, although they may prove to be incidentally so. The most important use of inquiry-related techniques is to support the instructional goals and objectives of the school. You, as teacher must decide how best to achieve these goals. Teaching through inquiry is not simple; it requires a well-prepared teacher to do an effective job. However, the rewards far exceed those found in the traditional classroom.

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CHAPTER 9

SCIENCE SAFETY*

The Legal System in Perspective

Contemporary United States society is among the most litigious (requiring intervention of the legal system to resolve disputes) in world history. According to Timothy Gerard, an attorney experienced in science education concerns:

> The connection between safety and the law is founded in reasonableness. The law only requires that a person be reasonable, that is, exercise good common sense. So, too, good safety consists mainly in behaving reasonably and exercising good common sense. A teacher does not need to worry about adopting quantities of unfamiliar habits in order to conform to what the law expects, to avoid being sued. Rather, a good teacher can avoid being sued by merely being reasonable and promoting a safe learning environment. (1986, p. 98)

It is prudent for citizens to consider the impact of this legal system upon their personal and professional activities, however, it must be kept in perspective to all other factions of society. Educators should thus understand federal, state, and local laws which influence their jobs, however, paranoia about being sued can seriously compromise good teaching.

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The purpose of this chapter is not to make teachers of science into attorneys, but to reduce their paranoia by raising their knowledge level of the more salient and applicable components of the law relative to science teaching. In addition, the protection afforded to reasonable and prudent teachers under our legal system will be presented.

Tort Law

> A Tort is a civil wrong not involving contracts. The term is applied to a variety of situations where one suffers loss due to the improper (but noncriminal) conduct of another. Courts hold those who commit torts liable in damages to those injured. The most common tort is negligence. (Reutter & Hamilton, 1976, p.)

In other words, a tort is an action, or inaction, by one person which results in injury or death to another. For the purposes of this chapter, it is an accident relative to the educator's job description. One of the major tort actions filed against science teachers stems from alleged negligence. This section will stress this type of behavior in detail.

Foreseeability

Critical to deciding the disposition of torts are two parameters: "foreseeability" and "reasonable and prudent judgment."

Did the person who caused an injury to another, especially a person in a position of responsibility--a teacher, attempt to foresee any accidents which might occur during the activity being undertaken, and did he or she attempt to eliminate that hazard? Foreseeability will, in turn, be decided based upon the performance of three duties of the teacher, including; Instruction, Supervision, and Maintenance of equipment and environment. These duties will be discussed in another section of this chapter.

Teachers must become atuned to assessing their educational environment for possible hazards and then to take appropriate action to reduce these identified hazards to "acceptable" levels. In some extreme instances, activities may have to be significantly modified or eliminated if the foreseeable hazards cannot be reduced to acceptable levels.

Reasonable and Prudent Judgment

In addition to attempting to foresee any accidents, teachers should ask themselves, prior to conducting all hands-on activities with students, questions concerning reasonable and prudent judgment. Would a reasonable and prudent person conduct this activity in the same, safe, manner as I am? Would my techniques be accepted as consistent with my peers? Is there something about the activity that I do not completely understand? Should I seek assistance from another person or other resource which could better apprise me of the information I need to conduct this activity safely?

Teachers must recognize that there is no clear definition of a "reasonable and prudent person" since the definition would vary with the situation, background and general understanding such a person would apply in the situation in question. This is one of the greyest areas of tort law.

The purpose for mentally reviewing such parameters as foreseeability and reasonable and prudent judgment prior to conducting any activity with students is to help assure the teacher that such components of their instruction are indeed safe and that he or she can pursue them with confidence.

Sovereign Immunity

Prior to 1967, public school districts could not be sued for torts committed by themselves or their agents or employees. This was due to a carryover of a British law which basically stated that the king and his court could do no wrong so they could not be held liable for injuries to another. In this country government employees, were paralleled to agents of the king and also afforded this same protection.

During the mid 1960s the Doctrine of Sovereign Immunity, which stated that any governmental operation could do no wrong and therefore could not be sued without it's consent, was repealed. Governmental agents, and educators being governmental employees, indirectly, could now be sued for tort mishaps.

This was a significant change for all government agencies and employees. Government agencies responded in one of two manners. One response to this change was swift, predictable, and costly. Governmental agencies, including schools, began to purchase liability insurance.

The second response, to the replace the sovereign immunity doctrine, with a better and fairer concept. The new doctrine was called the "Save Harmless Provision" and it became one of the most powerful pieces of legislation that a teacher could have afforded them relative to tort liability.

Save Harmless Provision

After the change in the Sovereign Immunity Doctrine, governmental agency personnel were initially confused as to how to protect their organizations and employees from liability. Especially since, in many instances, governmental agencies were the bodies responsible for drafting, enforcing and funding the regulations necessary to protect citizens and organizations from injuring each other.

Educational agencies were not immune from this paradox. However, the legislation that did finally emerge was one of the most powerful benefits an educator can realize relative to tort liability. The language of such provisions is similar in most states, and is reflected in the example below from the state of Iowa.

> Although the teacher, as well as others affiliated with the school system may incur liability, even while utilizing reasonable and prudent judgment, governmental subdivisions would be required under the save harmless provision of the state code to protect the teacher and pay any damages incurred. The only exceptions to this requirement would be cases involving malfeasance (unlawful acts) of willful neglect. (School Laws of Iowa, p. 439)

It is obvious that should an accident occur within the scope of the teachers employment duties, that the district and the teacher could be sued for negligence. However the school district would be responsible for protecting the teacher and paying all costs incurred during defense trials and for any monetary losses suffered due to liability. The only exceptions to this rule would be cases in which the plaintiff (injured party) could prove willful negligence or prove that the teacher broke the law.

Willful negligence is very difficult to prove, especially if the teacher makes any attempt to use reasonable and prudent judgment and to foresee hazards. However, breaking the law can occur more easily than imagined, especially when considering the "goggle law" instituted in most states. This law will be discussed in greater detail in another section of this chapter.

Liability Insurance

In order for governmental bodies including schools to protect their employees from tort suits under the save harmless provision they began to purchase liability insurance. Today, the great majority of school districts purchase such insurance for all employees.

The premium costs for securing liability insurance can generally be purchased with funds from the district's general fund, any other fund, or levied in excess of any tax limitation imposed by statute.

Educators should be cautioned that although liability insurance is a protection, it should be viewed as secondary to, and enhanced by, proper teacher conduct.

Some teachers will secure additional insurance from professional societies. Often, new teachers are pressured by sales representatives from local, regional and national insurance companies to purchase additional coverage for instructing in such subjects as science. The rationale being that since science teachers deal periodically with hazardous materials, they would be more difficult to defend in an accident. Teachers should not yield to such pressure without carefully first reviewing their district policy as well as that of the insurance company for redundancy. In many instances, such individual insurance policies will state, in the fine print, that "this is a secondary policy contingent on the fact that the insured has a primary policy covering tort liability." What this means is that such insurance will not be brought to bear in a suit unless the primary (school) insurance carrier defaults, or the value of the suit exceeds coverage of the primary carrier.

In some unusual teaching assignments, where one person fills multiple roles, additional outside insurance may be justified. If, for instance, a science teacher instructs and simultaneously drives the school bus for field studies, there may be justification for additional coverage. For, if an accident occurred and 30 to 40 students sued the teacher collectively, the suit could exceed the coverage of the primary insurance carrier and the secondary policy "could" come into play. Such a scenario would be exceptional rather than the rule for most teachers.

Statute of Limitations

Before a plaintiff (parent, student) can attempt to assess a defendant's (teacher) innocence or guilt relative to negligence under tort law, he or she would have to initiate the suit action within specific time frames. Generally speaking, papers would have to be filed with the county clerk within six months of the incident and action commenced within two years.

Since overt action concerning a tort liability case could begin years after the incident's occurrence, it would be wise for a teacher to compile careful records to protect himself or herself from future legal actions by the plaintiff.

Accident reconstruction should include information from all school personnel involved in any way in the incident; injured parties; student witnesses; nurses. A taperecorder is a good way to interview parties involved and to preserve this valuable information. Such records should be retained in a safe place until the statute of limitations is exceeded. If a suit is brought at a later date, information collected immediately after the event would be a very useful and powerful defense.

It may be wise to note that it is "generally" recognized by the courts that students below the age of seven years cannot be held responsible for their actions; between the ages of seven and fourteen years, they may be held responsible for their actions, depending upon the situation; and beyond fourteen years they probably will be held responsible. This generally means that teachers must protect very young students from nearly every type of foreseeable injury. This has serious implications concerning the types of hands-on activities the teacher should demonstrate or have students conduct. Can you foresee any accident occurring when children are conducting a certain activity and have you taken all reasonable precautions to eliminate them?

Negligence

Before a suit can be pursued very far against an individual, there must be some evidence that negligence was involved in the incidence. Negligence is generally defined as conduct that falls below a standard of performance established by law to protect others. Standards may extend to accepted practices for an activity which are endorsed by a profession or by knowledgeable persons within such professions. Techniques for handling, dispersing and student use of flammable liquids in academic settings may not be law in many states, however, guidelines concerning use of such materials would be available from such organizations as the fire marshall, Occupational Safety and Health Association (OSHA), National Science Teachers Association, and from publications such as Science Safety for Elementary Teachers (1984) and How to Avoid Being Sued While Teaching Science (1986) written by knowledgeable experts in the field of science safety.

Educators who have participated in safety inservice programs and who have received formal education in this subject in college level courses would generally be held to a higher standard of expectation by the courts. However, those who are not knowledgeable of such information cannot use ignorance as a defense for an accident. It is a teacher's professional duty to stay current in these areas!

In order for negligence to be proven against a person, the courts have generally held that the following four questions must be answered affirmatively. This is part of the process of deciding due care on the part of individuals such as teachers in positions of responsibility. Due care generally refers to one person's responsibility to care for another. Persons in positions of leadership generally have a greater responsibility to care for others than do those not in such positions.

1. **Did You Owe A Duty To The Injured Person**? Teachers must recognize that they are in an unique position relative to due care. They are responsible for the most precious possession many adults will ever have--their children. Parents, students, administrators, school boards, and society expect that the teacher will provide their students with a safe environment in which to learn. If the environment becomes unsafe, these same parents or guardians should

assume that the teacher would remove the students from the hazard.

For very young students, activities must be nonhazardous and reflective of their limited recognition of hazards, concrete reasoning skills, and cursory knowledge of science. Recall that for students below the age of seven years, they must be protected from all hazards and they cannot be held responsible for many of their own actions.

Teachers must have a working knowledge of their job responsibilities to address this question. Does your teaching duty extend to equipment repair, playground or hallway duty, or transporting students to events in your personal vehicle? A teacher must be knowledgeable of such questions relative to their teaching duties in order to prevent a minor incident from degrading to a serious accident.

2. Did You Fail To Exercise Your Duty Of Care? Failure to exercise reasonable and prudent judgment or not anticipating reasonable dangers which produce an accident could result in the teacher being held negligent. Failure to exercise care can range from doing something which is inappropriate for the situation to not initiating an action which would have prevented the incident.

An example of an omission resulting in an accident could be a field trip which a teacher is planning for which he or she forgets to send home permission slips to parents or guardians outlining the location of the trip, date, time of day, method of travel, and supervision provided. Although a permission form will not absolve a school, or it's employees, from responsibility during such trips, to conduct such excursions without them is foolhardy. The main purpose of such forms is to provide the parents or guardians the opportunity to decide whether their child should participate in the activity. For instance, if the child had acute hay fever and the teacher were planning to take a field trip to a natural prairie during the spring, the parents or guardians might decide to prevent the child from partaking in the event.

An example of an inappropriate action which could be viewed as negligent behavior for a science teacher might be providing very young students with concentrated solutions of acids and bases and telling them to move to a corner of the room and discover the properties of each by intermingling them.

(Concentrated acids or bases should never be used in elementary science classrooms!)

3. **Was Another Person (Plaintiff) Injured**? It may be obvious to state at this point that there must be some type of injury (physical or psychological) to one party before a serious suit could be brought against another person. However, in all liklihood, if the first two of these four questions were answered positively, this one will eventually be also. Luck can prevent injury when unsafe practices are undertaken for a while, however, the probability of injury increases with the number and seriousness of the hazards overlooked.

4. **Was The Failure to Exercise the Duty of Care The Cause of Injury To Another**? This may be the most difficult parameter for the injured party (plaintiff) to prove against the teacher. It is also the question which is most easily refuted by a safety conscious educator. Obviously, if any or all of questions one through three are answered negatively, this question would probably also. This should be the antithesis of concern for the conscientious, future thinking educator.

A teacher who endeavors to anticipate any reasonable accidents, uses reasonable and prudent judgment in selecting and conducting activities, makes a conscious effort to guarantee instruction appropriate to the student, establishes supervision adequate for the age level and environment in which students are studying, assures that all facilities and equipment are in proper working order, and emphasizes a safety consciousness with students, may still have accidents. However the liklihood of becoming involved in or losing an aggravated law suit on the basis of negligence would be minimal.

Contributory versus Comparative Negligence

Contributory negligence. Negligence can be divided into two distinct categories: contributory and comparative. Contributory negligence involves incidents in which the student contributes, in some way, to his or her own injury. This can happen by the student disobeying teacher's instructions, exceeding instructional guidelines or safety precautions, by conducting inappropriate activities, or by disregarding general rules of conduct.

Contributory negligence is "generally" an all or nothing situation in tort law cases. Either the student did, or did not, contribute to his or her own injury. If it is proven that the student did disregard rules which resulted in injury to himself or herself or to another party, the teacher is generally absolved of responsibility and he or she is removed from further involvement in the case.

Comparative negligence. By contrast, comparative negligence concerns incidents in which each party involved in the incident is assigned a percentage of blame. It is not an all or nothing situation as in cases judged under the contributory negligence clause. Currently the majority of states assess their negligence cases under this relatively new negligence system.

In some instances such a system could allow a fairer assessment of the responsibility for all parties involved in incidents or accidents in science settings. All monetary rewards are made according to the percentage of blame the courts decide each party must bear in such cases. If, for example, in a $1,000,000 comparative negligence suit, the defendant, a teacher is found to be 55 percent at fault and the plaintiff, a student to be 45 percent at fault, the monetary return to the student would be reduced by 45 percent of

$450,000 resulting in a net settlement of $550,000 for the plaintiff. Cases in which the teacher is deemed 55 percent and the student 45 percent at fault could occupy significant amounts of court time to resolve.

To the uninformed citizen, such a system seems to be simply a way for attorneys to generate additional employment for themselves, while reducing insurance claims. However, it is too early to assess the national impact of the comparative negligence system.

Duties of the Teacher

The classroom science teacher generally has three basic duties, which, when performed correctly, should help him or her avoid accidents and potential negligence suits. These duties are Proper Instruction, Adequate Supervision, and Maintenance of Equipment.

Proper instruction. This duty relates to providing the student with materials and concepts to study that are appropriate for his or her level of reasoning ability, physical and mental development, emotional development, and science background knowledge and skills. It would not be appropriate, for instance to use a sixth grade textbook for a gifted third grade student. Authors of such texts assume that a twelve year old has had certain experiences and knowledge to draw upon that a nine year old might not. Experience with the properties of such substances as alcohols (rapid evaporation rate, flammability, reactivity, explosive potential) may be a common assumption for most sixth graders, however, the experience with such volatile liquids may not be in the third graders background to draw upon.

In addition to using textbooks which are appropriate for specific grades, teachers should not attempt to "literally" interpret them for accuracy. The courts have ruled in the past that schools do not hire the textbooks--they hire teachers. In other words, a competent science educator should have students conduct only those activities in the text which are appropriate for their students. If some portion of the text does not seem clear, the properties of substances being incorporated are not clearly safe in the teachers mind, or the safety equipment or laboratory hardware are not available, the activity should not be conducted with students.

Once again, teachers must scrutinize textbook and materials for conducting activities with students and attempt to "foresee" any reasonable problems that could occur and use "reasonable and prudent judgment" in deciding which endeavors are appropriate for "their" students. If the hazards cannot be reduced to acceptable levels, the materials and/or activity should not be attempted. In some instances, certain activities may be appropriate to conduct with one class but not another in the same grade, due to the personality the whole class takes on as a result of it's collective individuals.

The introduction of PL94-142, which stated basically that all students are entitled to an education in the least restrictive environment, introduced another complication for the science teacher. It was now possible for students with varying degrees of physical, emotional, and intellectual handicaps to be "mainstreamed" in the same class. What should a reasonable and prudent teacher do in such a situation? Better judgment may indicate that the severely handicapped student should not partake in activities which involve materials which could potentially cause injury. However, federal law says that such students are entitled to the opportunity to partake in such courses.

The best recommendation for teachers in such a situation is to review as much information as possible about such "exceptional" students on a case-by-case basis and decide individually what is best and safest. Do not attempt to prejudge the ability of such students based on some previously held stereotypical bias. Many handicapped students need only a chance, and in most instances they realize that they must exercise exceptional caution due to their restriction. Teachers should review medical problems with the nurse and or parents and work closely with special education teachers and/or shop teachers in designing or amending activities and equipment which better accommodates the student's handicap. In addition, teachers might alter the physical room setting so the handicapped student can make the best use of his or her available senses.

A hearing impaired student should be moved to the front of the room where he or she could better observe hand signals and facial expressions. Visual cues for such auditory emergency signals as fire alarms and smoke detectors, should be developed.

A vision impaired student might be placed where auditory signals can best be received. Furniture should not be rearranged again without apprising him or her. Tactile (touching) senses should be used often to communicate with the student.

For the physically handicapped student, physical barriers should be removed. Special lab tables and protective equipment could be developed for the wheelchair bound student or those on braces or crutches.

For the speech and language impaired student, the teacher should attempt to articulate clearly words and phrases paying special attention to the mimicking that such students do.

In addition, teachers might explore the use of the "buddy system" in which the handicapped, or exceptional student, is paired with a willing nonhandicapped student.

Most important, the teacher should guard against patronizing the student. They recognize such special treatment and begin to perform to these levels of expectation. Handicapped and special students want most to be treated as much like anyone else as possible. The teacher must be the final judge in deciding how much an activity must be compromised for special students. If the compromise is too great to make learning the concept possible, the teacher may have to eliminate the student from participation in it.

Duty of adequate supervision. Assessing the ideal versus the practical student to adult educational ratio and attempting to reduce the ratio as the degree of environmental uniqueness increases are aspects of this duty. In other words, the greater the environment the students are experiencing differs from the typical classroom setting, the lower the student to adult chaperone ratio must be.

In a "typical," controlled classroom setting, one teacher per 24 first graders might be adequate; however, when these same students are studying the vegetation on the rim of the grand canyon, such a ratio would be woefully inadequate. Again, the teacher must "foresee" accidents and use good judgment in assessing a safe ratio.

It is always best to have school employees, preferably teachers, serve as chaperones for educational endeavors, since they are generally knowledgeable of the behavior of groups of students and are protected by school insurance. The next best type of supervision would be school endorsed parents or adults from the community who are known by school personnel.

When transporting students from one location to another, it is usually best to use school vehicles chaperoned by school personnel. School vehicles have been designed with student safety features included such as: warning and signaling lights and signs, specific aisle widths and seat and door construction. In addition they are driven by personnel who are accustomed to the noise and activity levels of students. They are also skilled at dealing with student discipline problems and are covered by school insurance.

Duty of equipment maintenance. Selection of the most appropriate materials for students and maintenance of such in good working order are elements of the third duty. Every effort should be made to assure that hands-on materials are properly designed for use by small hands with limited coordination. Small pieces which could be harmful if swallowed should not be used with very young students. Delicate glassware and open flames would also be questionable.

Upon selecting the most appropriate equipment, the teacher should assure that it is properly maintained. Special attention should be given to electrical equipment for proper grounding, frayed wires, missing grounding prongs on plugs, and proximity of such equipment to water. Glassware should be examined for cracks which might lead to breakage and/or cuts.

For those rooms which have water faucets, teachers should explore the addition of "splash gard" (Gerlovich, 1986) or "kleen eyes" eye/face washes. These chrome plated eye/face washes attach directly to the faucet, eliminating expensive plumbing costs. By simply pulling out a diverter pin, water can be directed through the faucet or up through the eye pieces to flush the eyes or face. This safety equipment should be seriously considered whenever students and/or the teacher use acids, bases, or salts in activities. Costs range from $50 to $75 each including adapters for various faucet sizes. Such equipment should be checked periodically for proper operation.

For upper elementary grades, where chemicals would be used more regularly in science classes, another good addition would be an "accessory drench hose". The six foot hose screws into a faucet and has a large hand operated spray head to direct water over large areas of the body. The sprayer head can be attached to a sink or magnetically to a plate on the wall. Again, such equipment should be checked regularly for proper operation.

In addition to these specific pieces of safety equipment, upper elementary teachers should be sure they have functioning fire extinguishers, appropriate fire blankets, proper chemical storage containers and/or cupboards, acid resistant countertops, places to secure more hazardous materials away from students, and appropriate areas for housing and displaying animals and plants. For more details concerning buildings; safety equipment; chemical storage; use of animals, plants and microorganisms, the teacher should refer to Science Safety for Elementary Teachers (1983).

If equipment or components of the physical plant (building) are discovered to be broken or in a state of disrepair, the teacher should **not** attempt repair, unless he or she is properly trained or licensed to do so. Instead, he or she should apprise the proper authorities of the problem, **in writing**, and leave repair work to those with proper training. Putting such needs in writing and then citing the safety problem being created, apprises the administration of the situation in an effective manner. The teacher should keep a copy of the memo in his or her files for future reference or until the equipment is properly repaired.

Lastly, teachers might wish to attempt some simulations of various science-related emergencies, to assess student response. Naturally, every effort would be made to protect the students during such simulation. Teachers might blindfold a single student then inform him or her that he or she has experienced a splash of an irritating chemical in the eyes. Using other students to protect the volunteer, the blindfolded student might then be directed to find the eyewash and wash the chemical from his or her eyes. The same type of simulation can be practiced for a student on fire or a student with a chemical splash on the skin. In most instances, students do not know the location of safety equipment or how to use it.

Teachers might arrange for competent individuals to visit the class and demonstrate the use of such common equipment as a fire extinguisher. In most instances the local fire department is happy to assist in such efforts. Students are often surprised and shocked at the high noise level of a carbon dioxide fire extinguisher being discharged in a closed room. They also have erroneous perceptions of how the chemical will travel and settle when discharged from the extinguisher.

The purpose of this section is to make teachers and students aware of proper operation and maintenance of equipment. In addition it should encourage them to recognize problems and the importance of notifying the proper authorities to maintain such equipment in good operating condition.

Avoiding Negligence Suits

In attempting to understand the legal system and its role in assessing negligence, it may assist the teacher to envision two pans of justice being balanced at a fulcrum. When a suit is filed, the prosecuting attorney will endeavor to amass as much evidence as possible against the teacher which would demonstrate the educator's mistakes and poor judgment. Teachers must become conscious of such legal maneuvering and attempt to amass all the support they can which demonstrates their efforts to protect students in educational settings, and themselves in legal settings. Some specific examples of such teacher efforts might include:

* attempt to foresee hazards and take measures to reduce them to acceptable levels.

* develop, and have students sign safety contracts which indicate they are aware of hazards and understand rules and safety precautions.

* develop and place diagrams and signs in strategic locations about the room that constantly remind students of safety concerns.

* conduct impromptu emergency simulation activities with students which apprise them of potential accidents and how to address them.

* become knowledgeable of federal, state, and local regulations related to safety issues in science education.

* assure that instruction is appropriate for students.

* assure that supervision is adequate for the type of students and the environment in which a science activity is being conducted.

* assure that equipment is working properly by using it regularly.

* keep administrators informed of safety concerns and equipment which needs repair.

* be consistent and emphatic in enforcement of safety rules and discipline.

* be sure to understand the purpose, outcome expected and hazards affiliated with all activities which are demonstrated or in which students participate.

* develop a safety conscious attitude in students by providing them a good teacher role model to follow.

* know if your state has an "Eye Protective Devices" or "Goggle Law" and be sure to enforce it!

- establish a representative library of strategic science safety materials (references in Appendix) and refer to them often.
- attend professional science teachers and safety meetings and remain current in the field of science safety.

Eye Protective Devices or Goggle Law

The eye protective devices law has been implemented in the great majority of U.S. states in an attempt to identify general eye hazards and to instill in teachers the need to use protective equipment with students to reduce the potential for eye injury. The law as it appears below is from the School Laws of Iowa (1982) and is typical of most states.

> ### Eye Protective Devices
>
> 280.10 Eye-protective devices. Every student and teacher in any public or nonpublic school shall wear industrial quality eye-protective devices at all times while participating, and while in a room or other enclosed area where others are participating, in any phase or activity or a course which may subject the student or teacher to the risk or hazard of eye injury from the materials or processes used in any of the following courses:
>
> 1. Vocational or industrial arts shops or laboratories
> 2. Chemical or combined chemical-physical laboratories involving caustic or explosive chemicals or hot liquids or solids when risk is involved
>
> Visitors to such shops and laboratories shall be furnished with and required to wear the necessary

> safety devices while such programs are in progress.
>
> It shall be the duty of the teacher or other person supervising the students in said courses to see that the above requirements are complied with. *Any student failing to comply* with such requirements may be temporarily suspended from participation in the course and the registration of a student for the course may be canceled for willful, flagrant or repeated failure to observe the above requirements.
>
> The board of directors of each local public school district and the authorities in charge of each nonpublic school shall provide the safety devices required herein. Such devices may be paid for from the general fund, but the board may require students and teachers to pay for the safety devices and make them available to students and teachers at no more than the actual cost to the district or school. (1982, p. 277)
>
> "*Industrial quality eye-protective devices*," as used in this section, means devices meeting American National Standards, Practice for Occupational and Educational Eye and Face Protection promulgated by the American National Standards Institute, Inc. (1979)

Recall that this is law! A teacher who does not require appropriate eye protection during activities which could result in an eye injury to a student may be breaking the law. Such a case might not be judged in tort law, but rather in criminal law. Insurance coverage would also be questionable in such a case.

Appropriate eye protective equipment is available for a $2.00 to $4.00 per pair from a number of commercial science equipment companies, including:

Carolina Biological Supply Co., Lab Safety Supply Co., General Supply Corp., and Central Scientific Co. (See References for citations.)

To comply with the eye protective equipment law, teachers should be sure to order only those types of eye protective equipment which meet the criteria of the American National Standards Institute (ANSI). The criteria for meeting the ANSI standards for "industrial quality" eye protective equipment are as follows:

Lenses	minimum thickness of 3.0 millimeters mounted in frames meeting ANSI Z87 standards permanent identification of manufacturers trademark and/or ANSI Z87 logo
Frames	resistant to strong impact nonflammable fronts have permanent manufacturers trademark and/or Z87 logo
Testing	glass or plastic lenses must withstand impact of one each [sic] steel ball dropped from a height of 50 inches

Teachers should be sure that any eye protective devices they purchase bear the appropriate manufacturers trademark and/or the ANSI Z87 logo on the lenses and frames. This assures them that such equipment meets the ANSI and state standards for "industrial quality." It would also be reasonable and prudent for a teacher to have students wear their goggles anytime other students are involved in activities in the proximate area which could create a hazard to the eyes. Signs and diagrams placed in strategic places about the room stating "eye goggles worn here" or "safety practiced here" would also help students to accept the wear of such protective items. In addition, teachers should provide students with a good role model to follow by wearing their own goggles whenever the situation demands.

Ideally, every student involved in science activities would have his or her own pair of cover goggles. However, practically, students will periodically have to share such equipment. Students should be cautioned to wash the goggles in a soap and water solution or with a general antiseptic before they wear them.

Increasing numbers of very young students are beginning to wear contact lenses. They should be counseled to wear protective cover goggles just like any other student involved in a science activity in which the potential for an eye injury exists. In addition, the teacher might want to place a red "c" next to the student's name indicating that they are wearing contact lenses. This would be a subtle, but constant, reminder that, should this student be involved in an eye emergency, the teacher should be on the alert for contact lenses.

Students with street wear, or general safety glasses should also wear safety goggles whenever an eye hazard exists in a science activity. Cover goggles will prevent ricocheting particles and liquid aerosols from contacting the eyes, whereas glasses generally will not.

If students are wearing glasses with photogray or photochromic (darkening) lenses, they should not engage in a science activity immediately after entering the room from outside. Reasonable and prudent judgment would suggest that the lenses be given a few minutes to lighten prior to the student's engagement in an activity in which clear vision is a must. In addition, the teacher might close the windows and have the student, wearing such glasses, keep his or her back to such sources of radiation to prevent the lenses from once again darkening. Cover goggles should be used with such glasses also.

Any student who continually removes his or her protective goggles during activities in which they should be worn should be disciplined immediately and emphatically. If the problem becomes persistent, the student must be removed from the privilege of partaking in the science class. It is better to discipline the student than to have him or her lose the precious gift of sight.

Cover goggles are not the most comfortable items to wear, especially in hot, humid environments, however the piece of mind they provide far outweigh the temporary discomfort they produce. It has been said that 70 percent of what we sense is through visual stimuli. By providing a good role model, enforcing a few rules, and assuring that proper equipment is being utilized, a teacher can help students protect their most valuable and beautiful eyes.

Case Studies

The information provided in the following case studies is provided to assist the educator in understanding the disposition of the courts and juries in deciding certain types of negligence within tort law. They should help teachers to comprehend the types of information they may want to be sure to collect if they are involved in an accident.

Recall that some states have enacted the requirement that school employees be defended against liability whether or not the school has insurance. Teachers should know the legal situation in their respective states relative to such save harmless provisions and insurance.

The lawsuits which are presented here are limited to those which were appealed and thus published. Those cases which are resolved outside the court system, or not appealed will generally not be published and thus distributed. Therefore these cases, at best, are very limited in their representation of the legal cases involving school science accidents.

If an incident, or accident should occur involving a science teacher, he or she should involve legal counsel early, if repercussions are expected. Do not assume that the issue is not serious until you have a court date. It is best not to discuss the "details" of the case with anyone, not involved in the incident until it is settled.

The best defense for a teacher in such cases is to use good judgment, attempt to foresee any hazards and reduce them to acceptable levels, use appropriate instruction, assure adequate supervision, and attempt to maintain equipment and facilities in proper working order. If an accident should occur after taking all these precautions, the teacher can generally have faith that the courts will support him or her. In the opinion of Timothy Gerard, attorney-at-law and consultant on science safety:

> The law allows that accidents do happen, sometimes through the fault of no one. You cannot prevent every accident, just as you cannot prevent every lawsuit. But being safety conscious will help minimize your risk of accident and your risk of being sued. A teacher with a good safety record and a good reputation for safety will make a far better impression in court than one whose practices have been marginal. The law only requires that you be aware of the risks and take reasonable precautions. As long as your conduct conforms to the standards of the profession, and you attempt to foresee relative problems, you have met your legal, moral, and professional responsibilities. More importantly, you have provided your students with a safe, yet stimulating and effective learning environment. (1984, p. 27)

For convenience, the cases reviewed here will be divided into two categories, those in which the teacher was found liable and those in which he or she was not.

Teacher Found Liable

In Bush versus Oscoda Area Schools (1976) a student was burned when a container of methanol ignited in the classroom. Due to overcrowding, the mathematics room was being used to instruct students in science. The room contained no fire extinguisher, fire blanket, fire alarm, storage or ventilation facilities, water, shower, or other equipment normally associated with science. The methanol was stored in a plastic jug which was allegedly damaged and split. Open flame alcohol lamps were being used due to the inavailability of gas for bunsen burners.

The injured student claimed negligence due to improper handling and storage of the alcohol, failure to warn students of the hazards in handling methanol near flames, failure to educate students in the use of fire equipment and failure to have fire alarm equipment in proper working order.

The teacher was found negligent, however the principal and superintendent were absolved since they were not informed of any problems by the teacher.

In Simmons versus Beauregard Parish School Board (1975) the school was held negligent for lack of teacher supervision of a 13 year old student who built a volcano in which he incorporated a firecracker for power and visual effects. The volcano was designed as part of a school science exhibit.

In Guerrieri versus Tyson (1942) two teachers were held liable for injuries to a ten year old student when they held his infected finger in boiling water. The court ruled that the situation was not an emergency and that the teachers were not qualified to use such treatment to address the problem.

Teacher Not Liable

In Gaincott versus Davis (1937) an elementary student was injured by falling from a chair. The student was attempting to water a plant used in nature studies at the time. A glass bottle was being used to transfer water from the tap to the plants. When she fell, the glass bottle broke, cutting her hand. The court found that there was no breach of duty and thus the teacher was not liable.

In Wilhelm versus Board of Education (1962) two students were injured when they attempted to mix some chemicals stored on the science room shelf. The two 13 year olds were working on science projects with teacher approval, in a laboratory with the door closed. The students knew the chemicals were dangerous and thus the court ruled that the students were contributorily negligent for such conduct.

In Madden versus Clauser (1971) a student was poked in the eye with a pencil while the teacher was briefly out of the room. The students apparently began to fight over the pencil in the teacher's brief absence, resulting in the injury. Because of the brief period of time involved in the incidence, the court ruled that the teacher's presence would not have prevented the accident, therefore no negligence was assessed.

In many ways a teacher's legal liability, within the context of our suit happy society, is a study in paradoxes. A teacher is generally recognized as the moral underpinning of our society, the citadel of citizenship in communities throughout the country, dedicated individuals who are willing to sacrifice economic remuneration for the intangible reward of personal interactions with this country's greatest resource--it's children. How plaintiffs can file suit against such well meaning individuals is difficult to understand. However, as we all know, it does happen. The most effective defense for a teacher attempting to do his or her best under such conditions is to plan defensively. Know the law, then use your best judgment and care to provide your students with a quality education.

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CHAPTER 10

EVALUATING STUDENTS AND ELEMENTARY SCIENCE PROGRAMS

Stimulating students to use inquiry techniques will be little or no problem. But a major problem that teachers face is how to "evaluate" the efforts. Currently it seems that test scores are the only things that count anymore. Yet the really important results of schooling are those that take years to learn and measure--good attitudes, citizenship, ethics, a sense of moral obligation to humankind, care of property, recognition of the rights of others. . . to list but a few. But such philosophizing will not help you convince parents or school trustees that their children are learning something worthwhile in science.

So, we are presenting selected evaluation techniques that are easily applied to science instruction. Let us first focus on two concepts of evaluation as a feedback mechanism.

Measuring Student Performance

Formative and Summative Evaluation

A basic objective of any evaluation system is to determine the extent to which the intended learner objectives are being achieved and the impact that the instruction or assignments are having on the learners. To accomplish this evaluation objective, two additional evaluation methodologies are used by educators: (1) formative; and (2) summative. Michael Scriven (1967) first suggested these modes.

Formative evaluation. Formative evaluation is designed to provide feedback in a rather immediate sense. Formative instruments are designed specifically to monitor selected aspects of any assignment or to determine where learning problems are emerging. By using formative evaluation, problems may be quickly identified and corrected. For example, if some methodology is being used that causes the students to do poorly, through formative evaluation quick remediation may take place. Often the teacher gives assignments but does not check the students' work until the conclusion of the unit, which is usually too late. By continually checking the "small steps," the teacher may identify instructional problems. This means that the teacher observes many different facets of a course while it is being conducted.

The rationale for formative evaluation is to provide data to the student and teacher so that they may make corrections--immediately, if not sooner! When students realize that science instructional activities are being monitored constantly, they tend to become more responsible and more productive. The instructional climate and total program environment become positive and supportive. This is precisely the kind of learning climate that the teacher always ought to foster when teaching. Conversely, classes have "gone on the rocks" because the teacher was not evaluating student activities over short periods of time, but waited until the very end of the course or unit to accomplish a one-shot final evaluation.

Only a few selected science items need to be checked in any one formative evaluation. These items would all be based on the stated or intended learning objectives. One does not need a lengthy set of test items. The important point is that the feedback is collected while there is adequate time to make adjustments for the student.

Using formative evaluation is much more subtle than simply specifying performance objectives. Formative evaluation requires that the teacher carefully observe a selected set of experiences for all participants. For example, in most science programs, some form of activity is used to build a cluster of skills for future use. A teacher subscribing to formative evaluation monitors the skills and, when a student performs inadequately, a new set of experiences that relate to the instructional objectives are provided. To correct any noted learning deficiency, it is important not to wait until the "unit exam." Thus, periodic correctives are an integral part of the formative evaluation plan.

One simple method by which to record formative data is to tabulate the absolute numbers or percentages of both individual and group activities. The teacher can compare group data on a graph so that the directions of the students could be displayed for instant visual analysis. Or, prepare a checklist with traits to be evaluated. A simple mark by a child's name would indicate that you observed the trait.

The essential characteristic of formative evaluation is that "hard data" are being collected for decision-making. But, more importantly, corrections are built into the scheme, so that feedback is used when it is needed most--not stored for future judgment. In short, use some reteaching, peer tutors or small cooperative learning groups so that those who do not illustrate the behavior have an additional experience and concomitant success.

Summative evaluation. Evaluation that is conducted as the final or concluding task of a unit is called summative evaluation. We should note that summative evaluation may be the final formative evaluation of a course or unit. Summative evaluations may take several forms, as long as they are consistent with the prescribed objectives of the unit, course, or module. Again, summative data can be tabulated as absolute responses, and then a percentage is calculated for each item. Comparisons between students also can be made from summative data (but not from the formative measures). The final grades is, of course, determined by the summative evaluations (note the use of the plural). Good teachers do not have one summative evaluation. They place evaluations at logical points in the course, such as at the ends of units, chapters, modules, or learning activity packages. The summative sets can then be arranged in a profile to illustrate the sum of evaluation activities. Formative data thus provide feedback, that is, a plan to help the learner; while summative scores lead to "grades" or to "judgments" about the quality of the performances.

Of course, it may be argued that formative and summative techniques will cause the teacher to change directions for several students. We agree and submit that if these techniques are properly used, the objectives of the entire class may even be altered.

Success is the underlying goal of this technique. If a science lesson needs to be modified because of unrealistic expectations (objectives), then why not alter it?

Perhaps the most convincing advantage of the formative and summative model is that there are no "surprises" at the end of the prescribed work. With early feedback evaluations built into the system, all elements should stress student success.

These two evaluation "philosophies" (if you will) are implemented through a variety of tests or evaluations. Let us examine some of them now.

Achievement Tests

Regardless of philosophy the schools must focus on achievement variables of evaluation. Achievement tests are constructed to assess a student's terminal behavior or the expected behavior or attainment of the student after completion of a chapter, unit, module or course. Achievement tests are developed to assess characteristics of the present behavior or performance. These scores show a level of present skill development.

Achievement scores provide two types of information: (1) the student's level of skill and/or knowledge relative to an established level of mastery, and (2) the relative ordering (rank) of the student's score in relation to the rest of the class. The first type of information is classified as a criterion-referenced measure. These measures depend upon an absolute standard of quality. This means that the student either has or has not acquired the predetermined mastery level of the science skill. The degree of skill attainment is usually stated in some descriptive term. The second type of information (relative ordering) is usually referred to an norm-referenced since it compares a student with other students in a select group. Norm-referenced tests are those most commonly used for local, state or national comparisons.

Criterion-referenced tests. A criterion referenced test is one that is intentionally designed to produce scores which may then be directly interpreted regarding attainment of previously specified performance levels related to mastery of the subject. These performance levels are established through the definition of the domain or group of behaviors or sets of knowledge which the student should be able to perform or know at the end of a unit, module, or course.

In this regard, it is absolutely essential that performance objectives be clearly stated. The essence of criterion-referenced testing is to test whether a specific learning objective was accomplished or not. For example, assume that one objective was, "the students shall serial order eight blocks of varying sizes, from the shortest in height to the tallest in height, with no errors in ordering." In this case you could test the children either by using a series of sketches illustrating various orders, including the orrect order; or you could ask each student to perform the task. Note, in this example, the task is to order the objects. Neither time nor rate is considered, thus these criteria would not be judged.

The technique of specifying objectives, teaching to them, and testing to them specifically is now called "curriculum alignment." In theory it sounds easy. In practice it takes discipline and curriculum planning.

Mastery. Assumed within criterion-referenced tests is the concept of mastery. Defining mastery has been and continues to be a problem for all science educators. Mastery learning has been defined in a variety of ways. Benjamin S. Bloom (1968) summarized the basic premise by uniting many approaches. He observed that if a normal distribution of student aptitude or potential is assumed, i.e., a large number of students have average potential, with a smaller number having either more or less than average potential, and the type and quality of instruction plus the time allotted for learning to occur is adjusted to meet the individual needs and characteristics of these students, then most of the students should be expected to attain a mastery level of the subject.

Two types of mastery were noted be Bloom: (1) skills or knowledge which allows the student to transfer the learning of a new situation, and (2) the number of items passed on a test. Related to these two types of mastery is the problem of whether to base mastery upon the selection of a correct answer and/or the production of an answer. The previous example of serial ordering illustrated that the mastery could be determined by the selection of a pictorial description or a proper order as opposed to the actual performance of an accurate ordering. If transfer of learning (application) is to take place the student should actually be able to produce a proper response in a variety of situations.

Cognitive domain. The cognitive domain that was presented originally was based upon Bloom's cognitive taxonomy. Thomas S. Baldwin (1971) presented an adaptation that was originally designed for industrial arts teachers but which appears to be as efficacious for science educators who are involved in writing test items. Baldwin's adaptation was developed to satisfy two basic goals. First, a taxonomy should be easily understood by educators who are generally unfamiliar with educational theory; and second, the revised taxonomy should include the various cognitive levels performed by students of science education. Thus, if used for planning and evaluating the cognitive domain would ensure inclusion of cognitive levels relevant to any program or project. The four subcategories of Baldwin's cognitive domain are discussed below.

Knowledge. Test items developed to test student performance at this level require recall of information which students previously experienced or learned. The major factor here is memory of information. For example, the student may be asked to give specific information or conditions required to produce snow.

Understanding. Test items for this level require responses that go beyond that which has already been learned and/or practiced. These responses may be in the form of interpretations noting similarities or differences, and analysis of situations or problems, For example, the student may be given a particular weather situation developed as a case study and then the student is asked either to produce or select an interpretation of what may happen.

Application of knowledge. These test items require the student to make use of previously learned information. Neither the problems nor the information are new to the students; hence, the necessary responses should be relatively routine. For example, a question could be asked concerning a factor in the process of hail production in clouds.

Application of understanding. Test items at this level requires understanding of the material to give an appropriate response. Several components of the problem have been experienced by the student before, but a minimum of one element must be new to the student. This new component can be either a part of the problem or the solution.

For example, a student may be given a diagram of a simple electric circuit and the student is to select which of four statements describes the circuit's operation.

All of the above tend to evaluate achievement of cognitive objectives providing that each student is given adequate experience and practice at the skill. Yet, there are other equally important objectives in science that must be evaluated, for example, process skills.

Evaluating Process Skills

To aid, there are a few extensions that might be applied to the traditional report card. However, in science the report card extension would stress the processes, with just a mere passing over of the content.

We are very cognizant that many of the criteria that will be listed require a great deal of subjective judgment on the part of the teacher. But being subjective is not to be confused with being arbitrary. Subjectivity is that element of judging that requires a knowledge of the criteria and a comparison of the individual's performance judged by those criteria. Think for a moment about the judging of a track meet where the criteria are clearly defined for the sprints. Now compare these criteria to those of gymnastics or diving. In the latter areas the criteria are known, but subjectively applied. This analogy applies to the judging of inquiry in the classroom.

Figure 10-1 presents one of many possible sets of criteria. You must select the criteria that you think are appropriate to your science classes and then apply them to each student. Over a period of months, you'll observe a definite pattern of science process behavior that indicates the relative growth from using an inquiry strategy, or perhaps a cooperative learning model.

There are many other forms that you can use to evaluate processes. Note that Figure 10-2 was developed and used in the Spokane, Washington, public schools. At the time this form was devised, Spokane had no formal process instrument. This record was produced by a committee of educators and is oriented directly to Spokane's elementary science program, Science Curriculum Improvement Study (SCIS).

In this form, observe that every element is behaviorally oriented. Classify each of the criteria according to Bloom's six categories. You will discover that, surprisingly, there are no knowledge-level criteria. The criteria used are all at the Comprehension, Application, Analysis, or Synthesis levels--all involving higher-level cognitive behavior. You will also observe a few affective qualities as well as one or two criteria involving psychomotor activity.

Criteria for Evaluation in Science	Ranking by Month*			
	Oct.	Nov.	Jan.	Feb.
Curiosity -- awareness of environment, questioning attitude				
Initiative -- ability to work independently without direct guidance				
Willingness to risk failure to try a novel idea				
Sense of responsibility to the group				
Powers of observation				
Organization and purpose in attacking a problem				
Care and use of equipment				
Recordkeeping -- completeness and form				
Communication -- relevancy of message				
Ability to classify information				
Ability to formulate generalizations				

*The attitudes and behaviors listed are evaluated on a 1-5 scale, with 1 indicating "Not Usually Observed," a 2 indicating "Observed Very Infrequently," a 3 "Observed on Occasion," a 4 "Observed Rather Frequently," and 5, "Always Observed." A "N/A" is used for "not applicable." Criteria that will be evaluated are those having special relevance to the current science objectives and program.

Figure 10-1. Evaluation of Pupil Progress in Science

Figure 10-2. Pupil Evaluation Record for Elementary Science Program

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(Note: Teacher retains in file--records grade on report card each quarter.)

Name of Pupil: ______________________________

Grade: _______ School Year: ______________

Key:

4 = Demonstrates great proficiency.
3 = Demonstrates proficiency.
2 = Demonstrates some proficiency.
1 = Demonstrates little proficiency.

Directors: Insert number in box provided for appropriate quarter.

EVALUATION CRITERIA

I. Curiosity
    A. Uses several senses to explore organisms and materials.
    B. Asks questions about objects and events.
    C. Investigates circuits and other systems actively.
    D. Shows interest in the outcomes of experiments.

II. Inventiveness
    A. Uses equipment in unusual and constructive ways.
    B. Suggests new experiments.
    C. Describes novel conclusions from observations.
    D. Proposes original models to explain observations.

III. Critical Thinking
    A. Uses evidence to justify conclusions.

B. Predicts the outcome of untried experiments.
C. Justifies predictions in terms of past experience.
D. Changes ideas in response to evidence or logical reasons.
E. Points out contradictions in reports by classmates.
F. Investigates the effects of selected variables.
G. Identifies the strong and weak points of a scientific model.

IV. Persistence
  A. Continues to investigate materials after novelty has worn off.
  B. Repeats an experiment in spite of appearance failure.
  C. Completes an activity even though classmates have finished earlier.
  D. Initiates and completes a science project.

Arrange--Each Quarter:

Quarter Letter Grade:
(Translate number average to letter grade.)

Transfer letter grade to report card for appropriate quarter

Teacher Notes: (include dates)

Source: Spokane, Washington, School District No. 81. Used with permission.

Specific Science Testing Mechanisms

As science is a "contact sport", it is essential to use some techniques that can measure achievement of cognitive, affective or psychomotor skills. Below are some ideas that represent a very "contact" oriented evaluation (Doran, 1987).

Applying. Students can be asked to plan or design an experiment or some means by which to tool an hypothesis. The teacher would examine the final plan for completeness and logic.

Students could be evaluated by conducting a demonstration for the class. This activity would probably be a team effort, as it usually takes two or three children to conduct demonstrations. Thus, performances would be very observable.

Students could be given data sets and asked to plot them on a graph or to prepare a table. For early experiences, the use of histogram should be used. In later experiences, graphing could be introduced when map reading is experienced in social studies.

Students could be given different tasks to perform, e.g., measure lengths or volumes, or pour water into plastic beakers to illustrate knowledge of volumes.

After actually conducting some activity, the students should be taught how to illustrate their findings by the use of principle figures, drawings or graphs. This activity allows a student to transfer the concrete to the more abstract. Further, standardized tests do make such transfers and require a student to make the generalizations or conclusions.

To test higher level skills, a teacher could give a picture or a graph and ask the students to (1) analyze the information, (2) predict what would take place next, and (3) illustrate the prediction on the original handout.

Another simple test is to give students a picture and ask students to identify patterns that appear.

Writing. A method by which to test science, reading and writing skills is to have students read selected passages from their texts and prepare a short summary about the reading assignment. Note how this helps students to transfer knowledge to a different form.

Teams of students could even prepare test questions (probably at the knowledge level) for other students. Encourage students to write tests using multiple choice, true-false, matching, and completion.

Again, reinforcing and changing the initial context of learning will help children to learn science.

Measuring Program Efficacy

Evaluating Science Programs

The previous sections provided an overview about student evaluation. Perhaps, of equal importance is the evaluation of the adopted sciences program. Implementing a previously adopted science program or the anticipation of a newly adopted one tends to be a source of elementary teacher frustration and anxiety. If teachers tend to rate the adopted program as being of poor educational quality, then there is a high probability that they will teach that science program as little as possible--if at all. However, one cannot attack any science program without the use of clearly stated and objective evaluative criteria. School districts often have various checklists by which to evaluate science programs. There are, however, far too many cases where adoptions are made somewhat intuitively and the teachers were not truly involved in the adoption. To alleviate these problems, let us now address the issue of science program evaluation.

Program goals and objectives. Throughout, we have assumed that present and future elementary school science programs will be activity oriented. Implied in the assumption is that elementary science education will continue to stress the scientific processes by which knowledge is acquired. Thus, a major goal for any program is the development of inquiry as a basis for study.

Whether the curriculum developers use performance objectives or some form of knowing what is expected of the learner is critical. While there is great division among science educators about the appropriateness of performance objectives, you need to have some concept of what is to be accomplished with the various activities. This is the essence of stated objectives.

Scope and sequence. There is the need for some logical development of science activities in a "scope and sequence" chart so that all the staff knows where the program is ultimately going. Traditionally, the concepts of scope and sequence have meant that a pattern of student learning experiences has been planned or identified. Scope implies the relative impact of the subject to be studied. When planning for depth or breadth of a definite science program, planners determine the scope. There is a great deal of divergence in the scope of topics covered in general science courses being designed for the elementary school; some will treat each topic in depth, while others will address similar topics in a less developed structure. Yet, all topics are selected and designed to provide wider exposure to the students so that breadth of the discipline is stressed.

The concept of sequence implies that the activities will be structured by a prescribed design. Sequence is usually determined by (1) logic--each topic follows a definite entry and exit; (2) topic--the concepts are sequenced to provide some Gestalt of the subject; (3) hierarchy--each topic is subdivided into specific learning increments, all being arranged in patterns of known to unknown to be expanded from simple to complex; (4) developmental stages--the concepts of developmental psychology, usually Jean Piaget's, are used; and (5) a combination of the four.

All science programs must be examined to determine the scope of topics and the order of sequencing. Since similar topics may not appear in all textbooks, a committee needs to compose a table of topic categories to be used in selecting a program or textbook that best meets the district's science goals.

Within the concepts of scope and sequence, there should be an analysis to determine if the science program is highly structured. A very highly structured program requires close adherence to the program per se. Such programs allow little in the way of teacher initiative. However, a structured program does have some built-in efficiency--i.e., you know what is expected and can spend your time implementing the program rather than creating new activities. Loosely structured programs, conversely, allow a greater degree of teacher latitude in the teaching of topics. But they require great use of time, energy and planning.

Accompanying the above is the concept of program flexibility. Most programs are built with a K-6 scope and sequence. Other programs tend to have the option of being supplemental to the program that the district has already adopted. In yet other cases, the district can select various components of the science program that ultimately reflect an eclectic approach to science.

Finally, under the concept of scope and sequence comes a determination about the balance of science subjects or topics that are presented. Some programs tend to stress a broad balance between the life and physical sciences. Others tend to stress the physical sciences far more than the life sciences. If a program has a strong life science component, has the district made the necessary commitments to maintain and deliver life science materials to you, or must you maintain your own life science stock? The latter decision is most crucial to the success of any science program that has a life science component.

Instructional strategies. A good share of this report is devoted to science instructional strategies. However, when evaluating an elementary school science program, you must consider the types of teaching strategies that are required. One important consideration is the relative amount of individualization that will take place. If a program requires a great deal of individual student work, then both you and the students must be taught how to effect that strategy. Because nearly all modern elementary science programs require inquiry in the broadest sense, school district administrative personnel and teachers, alike, must simply plan to conduct in-service efforts that address the many techniques that are included under the generic term of inquiry. Programs also vary from those that desire teachers to be very nondirective to those that are highly prescriptive.

Costs and maintenance. A critical decision area for many science programs concerns the initial cost of the program and the yearly replacement costs for expendable materials. When cost comparisons are made, there is the tendency to weigh the cost of a comparable textbook, which can be kept for about six years on an adoption cycle, against an activity-oriented science program. Ultimately, the evaluation of the alternatives must be made on a benefit theory basis since it will cost the district to teach science, no matter what the method. Which program will achieve the intended goals and objectives at the least cost tends to be the basis on which favorable or unfavorable decisions are made.

Teacher Reactions. If your school district has adopted a program or is in the process of field-testing one, then the "using" teachers should be polled to determine their perceptions. This type of evaluation should be designed to measure the interest of the staff, the use of teacher time in teaching science, and the extent to which the teachers perceive that the program is fulfilling the scientific literacy needs of the children. Two instruments that could be used in such an endeavor are illustrated in Figures 10-3 and 10-4.

Figure 10-3. Sample Instrument to Evaluate Science Programs

Kindly complete the following survey about our elementary science program.

1. Time survey: Please circle the number of minutes per week spent in the following areas:
    a. Planning time: (0-4) (5-10) (11-15) (16-20)
    b. Setting up materials: (0-4) (5-10) (11-15) (16-20)
    c. Student class time: (0-30) (31-60) (61-90) (91-120)
    d. Other science activities: (0-4) (5-10) (11-15) (16-20)
    e. The total time in minutes per week spent on science

    ____

2. Is the amount of time less than, equal to, or greater than that spent on mathematics, reading, and social studies respectively?

    ____

    ____

3. Did you find it necessary to supplement the science program with other science materials or activities?
    a. In almost all cases
    b. In most cases
    c. In a few cases
    d. In no case

4. If supplements were used, specify for which units or lessons:

    ____

    ____

5. What is your overall reaction to the science program?
   a. Very positive
   b. Positive
   c. Negative
   d. Very negative

6. If negative, please list specifics:
   ____

   ____

7. What unanticipated events have been happening in your science classroom?
   ____

   ____

8. In your opinion how do the students in your classes like the new science program?
   a. Like it very much
   b. Like it
   c. No opinion
   d. Dislike it
   e. Dislike it very much

9. What concern or problems have you had with the program?
   ____

   ____

Figure 10-4. Specific Technique Evaluation.

TEACHER EVALUATION

Activity:___________________ School:__________________

Grade Level:________________ Teacher:_________________

Situation (i.e. at desks, in open room, in field):

____

Time you allotted for activity in minutes: ____________

1. To what extent did the Field Biology materials provide a stimulus to expanding your teaching methods?
   - ______ a great extent
   - ______ a moderate extent
   - ______ very little
   - ______ none

2. To what extent were some of the science teaching techniques new to your repertoire of methods?
   - ______ most were new to me
   - ______ some were new to me
   - ______ few were new to me
   - ______ none was new to me

3. To what extent was the information on the Field Biology Module adequate to teach the "lesson" effectively?
   - ______ very adequate
   - ______ adequate
   - ______ inadequate
   - ______ very inadequate

4. To what extent were local materials available to teach the Filed Biology Modules?
   - ______ readily available
   - ______ generally available
   - ______ generally not available
   - ______ not available

5. How complete was the list of materials as stated on the Field Biology Module?
______ very complete
______ somewhat complete
______ somewhat incomplete
______ very incomplete

6. To what extent did the Field Biology Module provide adequate "hands on" science experiments for children?
______ very adequate
______ adequate
______ inadequate
______ very inadequate

7. To what extent was the Field Biology Module appropriate to your grade level?
______ very appropriate
______ appropriate
______ inappropriate
______ very inappropriate

8. To what extent was the Field Biology Module "novel" to you in teaching Field Biology Concepts?
______ very novel
______ novel
______ routine
______ very routine

9. Compared to other science activities, to what extent did you feel that your students were enthused about working the activities in the Field Biology Module?
______ very enthused
______ a little more enthused
______ about the same
______ a little less enthused
______ very unenthused

10. In your opinion, did the content of the Field Biology Module appear to foster a positive attitude toward biological science?
______ yes
______ no opinion
______ no

11. After completion of the Field Biology activity did you explicitly encourage your students to continue the investigation of the concepts on their own?
______ strongly encouraged
______ encouraged
______ neither encouraged nor discouraged
______ discouraged
______ strongly discouraged

12. In your opinion did the Field Biology Module stimulate an application of the concept to related activities, e.g. were you able to "branch out"?
______ at least two or more activities were generated
______ at least one activity was generated
______ no activities were generated

13. Was the quality of the activities comparable to those which are commercially available?
______ quality was much better
______ quality was a little better
______ quality was about the same
______ quality was a little poorer
______ quality was much poorer

Any additional comments?

From Jack Horne, 1982.

Using Student Evaluations

In addition to subjective teacher evaluations, you may use student rating scales during, or when completing, a game or simulation. For example, you can ask the participants to respond to the following types of questions by inserting a check mark where appropriate:

1. To what extent do you think that participating in the simulation was an effective learning experience?
   - (   ) Very effective.
   - (   ) Effective.
   - (   ) Ineffective.
   - (   ) Very ineffective.
2. How much do you like participating in simulations as compared to other instructional techniques?
   - (   ) I like simulations much better.
   - (   ) I like simulations a little better.
   - (   ) I like all instructional techniques equally.
   - (   ) I like other instructional techniques a little better than simulations.
   - (   ) I like other instructional techniques much better than simulations.
3. To what extent did you conscientiously participate in the simulation?
   - (   ) Very conscientiously.
   - (   ) Somewhat conscientiously.
   - (   ) Somewhat unconscientiously.
   - (   ) Very unconscientiously.

These three examples illustrate how the evaluative question is framed and is then followed by a continuum of responses. We have not developed other questions to ask the participants, but we have provided you with several sets of response continua as shown in Figure 10-5. All you have to do is generate the questions as are illustrated for one specific project in Figure 10-6.

Figure 10-5. Response Continua for Evaluation of Simulations

Very adequate
Adequate
Inadequate
Very Inadequate

Strongly agree
Agree with reservations
No opinion
Disagree with reservations
Strongly disagree

Very clear
Somewhat clear
Somewhat unclear
Very unclear

Greatly encouraged
Encouraged
No opinion
Discouraged
Greatly discouraged

Strongly favor
Tend to favor
No opinion
Tend to disfavor
Strongly disfavor

Almost always valid
Usually valid
Usually invalid
Almost always invalid

Very important
Somewhat important
Undecided
Somewhat unimportant
Very unimportant

Almost always supports
Usually supports
Usually unsupportive
Almost always unsupportive

Very satisfactory
Satisfactory
Undecided
Unsatisfactory
Very unsatisfactory

Very good quality
Good quality
Uncertain
Poor quality
Very poor quality

Modified from Donald C. Orlich. Designing Sensible Surveys. Pleasantville, N.Y.: Redgrave Publishing Co., 1978, p. 55. Reprinted with written permission.

In addition to these forms, observe the next model of a student evaluation form. This form was used by teachers to obtain student opinions or reactions to science materials that were being field tested by elementary teachers.

By the way, the students were generally very favorable toward actually conducting or doing science activities! See Figure 10-6.

Figure 10-6 STUDENT EVALUATION

Activity:

Grade Level:

Your teacher is helping with a project to design science lessons. You can help with the project by answering a few questions about the lesson you have just finished. Please remember that the questions are about the lesson, not about the teacher. Do not put your name on this paper.

Check each statement to tell us how you agree or disagree with the statement.

1. I learned something about field sciences that I didn't know before.
   ______ strongly agree
   ______ agree
   ______ disagree
   ______ strongly disagree

2. I like being able to do science activities, rather than just reading about them.
   ______ strongly agree
   ______ agree
   ______ disagree
   ______ strongly disagree

3. I could easily understand the science lesson.
______ strongly agree
______ agree
______ disagree
______ strongly disagree

4. I would have liked it better, if the teacher had just told us about the lesson instead of having us to do it.
______ strongly agree
______ agree
______ disagree
______ strongly disagree

5. The lesson was well explained before we started.
______ strongly agree
______ agree
______ disagree
______ strongly disagree

6. This lesson makes me want to do more of the activity on my own.
______ strongly agree
______ agree
______ disagree
______ strongly disagree

7. This kind of science lesson makes me interested in science.
______ strongly agree
______ agree
______ disagree
______ strongly disagree

8. I would rather read about science than do a science activity.
______ strongly agree
______ agree
______ disagree
______ strongly disagree

9. If you were the teacher and you were going to teach this science lesson, what changes would you make?

From Jack Horne, 1982.

By systematically conducting a series of brief evaluations, you will be collecting the kinds of evidence that form the basis of an accountability system. A combination of this type of evaluation instrument and others previously mentioned will be adequate for fulfilling the need for accountability. This can be your opportunity to improve student performance for those higher categories of Bloom's Taxonomy.

Quite obviously there are many other evaluation models that could be illustrated. It is our intent to show simply that evaluation of science requires measures somewhat different from the traditional measures of cognitive abilities. Teachers do have anxieties about evaluating students in their classes when they must use "processes." The previous discussion might have given you a few pointers from which to proceed would also suggest that you convene an ad hoe committee to study the general problem of science evaluation and that you and your colleagues prepare sets of materials for your school district that would be apropos to the science program being used. After all, the essence of science is involvement. What better way to lose a fear of science than by getting involved in it.

Conclusion

We assert once again that the more you know how to teach or interact with your students, the more likely it is that you will discover a teaching style that each and every one of them will like. Liking and succeeding in school is a basic principle. As teachers, you owe it to your students to motivate them in some way to be successful. As Benjamin S. Bloom so dramatically noted in his paper on mastery learning (1968), interest is a function of success. For too many years, we have operated schools according to the converse of the Bloom formula--success is a function of interest. In other words, if you want students to be interested in learning and in its related activities, then, most importantly, and number one, students must be successful in school.

When teaching science, you can generate enthusiasm among the students in your classes. You can inspire individuals to discover, to question, and seek. You can break the monotony of dull classes by using interactive techniques. You control the learning environment. Structure this environment so that everyone in it will be highly motivated and interested in learning science. It is the very least you can do or, perhaps, . . . the very most!

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Appendix A. Outline of Methods Course Content and Laboratory Time

EL/SE 311 - Teaching Elementary Physical Science

Spring Semester 1987	Dr. Donald C. Orlich
MWF - 11:10-12:00	Department of Educational
W Lab - 11:00-1:00	Administration & Supervision

The purpose of EL/SE 311 is to provide a set of prerequisite entry skills to prospective elementary teachers so that they will understand science, enjoy teaching science, become advocates for science and encourage their pupils to enjoy success in science.

GENERAL OUTLINE

I. Orientation to Science Education
    A. Background
    B. Trends
    C. Processes of Science

II. Objectives of Science Education
    A. General Goals
    B. Student Learning
    C. Performance Objectives

III. Sequencing and Hierarchical Analyses
    A. Concepts of Sequencing
    B. Taxonomies Applied to Science Instruction
    C. Textbook Content Analysis

IV. Lesson Planning
    A. General Techniques
    B. Classroom Realities
    C. Commonplace Activities

V. Questioning Strategies
    A. Research Bases
    B. Technique
    C. Applications

VI. Inquiry
    A. Inductive Techniques
    B. Problem Solving
    C. Discovery
    D. Deductive

VII. Classroom Management
    A. Small Group
    B. Materials and Resources
    C. Safety
    D. Handicapped Children

VIII. Evaluation of Science
    A. Curriculum Alignment
    B. Activity and Performance Methods

EL/SE 311 - Teaching Elementary Physical Sciences

Spring Semester 1987
MWF - 11:10-12:00
W Lab - 11:00-1:00

Dr. Donald C. Orlich
Department of Educational
Administration & Supervision

The goal of the laboratory is to apply basic concepts, skills and processes in a safe environment. The laboratory will emphasize a "hands-on" or "experiential" approach to science teaching.

GENERAL LABORATORY SCHEDULE

Week	Theme
1.	Applying the processes of science instruction.
2.	Determining science and sequencing objectives.
3.	Examining the precursors--SAPA, SCIS, ESS.
4.	Incorporating astronomy activities--Part I.
5.	Analyzing textbooks for astronomy content.
6.	Constructing science learning centers.
7.	Incorporating astronomy activities--Part II.
8.	Questioning via microteaching.
9.	Developing inquiry skills--Part I.
10.	Incorporating physics concepts--Part II.
11.	Developing inquiry skills--Part II.
12.	Analyzing physics content in elementary school science textbooks.
13.	Teaching science to handicapped pupils--SAVI/SELPH.
14.	Incorporating physics concepts--Part II.
15.	Using activities to evaluate student success.